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The First Astronauts

I'll put a girdle round about the earth
In forty minutes.
—*A Midsummer Night's Dream*, II, iv, 175.

We salute Major Yurii Alekseevich Gagarin for his great achievement in orbiting the Earth! We salute him for his courage in facing the unknown! We salute the many unknown engineers, scientists and technicians whose work in designing, building and launching *Vostok* made his achievement possible!

Major Gagarin's single exploit gives him a number of "records"—first man in space, first manned rocket flight, highest flight, world speed record, and fastest round-the-world flight. No doubt there are many others, but they need not concern us here; to be frank, we find some of the attention paid to athletic and "technical" records both tedious and unprofitable (does it really matter if man can travel at 400 miles/hr. on land or 200 miles/hr. on water?—if it is necessary to use such speeds it is more convenient to go by air) and we should be sorry if too much effort was expended on obtaining or equalling astronautical "records." There is no merit in clipping a few seconds off the orbit period (no human being is likely ever to equal Puck's time; Major Gargarin did not take much longer than the practical minimum); future flights must be undertaken for scientific research and exploration, as this one was.

Wednesday, 12 April, 1961, is a date that will go down in history—it is certainly a red-letter day in the history of astronautics. That it is a date only three-and-a-half years after the launching of *Sputnik I* is an indication both of the effort that has been put into this new technology and of the rate at which it is developing. If this rate of progress is continued, man may have orbited the Moon within the next three-and-a-half years—we will not be so rash as to predict that he will land upon it within that period, although even that would not surprise us.

The official Russian announcement stated: "The victory in the exploration of the cosmos is regarded by us as not only the achievement of our people but also of entire mankind." That is true; it is an achievement of which all mankind can be proud, although few have participated directly in the work leading up to it. Yet we cannot avoid the fact that others also hoped to be the first to place a man in space, so we also sympathize with our American friends who have lost this "race." It was within their power to have won it, but by entering for all the races at the meeting they obviously increased the odds against their winning the only race (the big one) the Russians ran in. As far as we can judge, the overall American space effort is much larger than the Russian one but because it is also more broadly based it cannot hope to catch up with the Russian programme in this particular field

It would be regrettable if the understandable desire to catch up caused America to rush its own man-in-space project and this led to fatalities.

We are happy also to salute Commander David Shepard for his great flight. As a technical achievement it does not rank equal with Gagarin's—to say that is not to belittle all the work the Americans have put into the Mercury project, but only to recognize the fact that an even greater triumph awaits them a few months ahead. Leaving aside the technical aspect, however, and turning to the more human side of astronautics, it is clear that there is little to choose between the two flights. Both astronauts displayed great courage and endurance. The Major had to endure a longer period of acceleration than the Commander—and a much longer weightless period (but both of them found that quite agreeable). The landings were dissimilar, but each came down on the medium to which his Service has accustomed him.

On the day of Major Gagarin's flight, one of the London newspapers reported that when the press officer for the U.S. astronaut team was awakened and asked for comment on Russia's feat, he yelled into the phone: "Its 3 a.m. in the morning, you jerk. If you want something from us, the answer is 'we're all asleep.'" Now that may be an incorrect report or even a complete fabrication, which is why we do not reprint the officer's name; we certainly do not agree with the implication which the newspaper probably intended us to read into the item and which has also been apparent in some cartoons. Our only reason for giving the story further circulation is this: if America, with all its many space activities can be suggested to be asleep, then Britain is not just asleep, but *dead.*

Dead. . . . The British space programme is stillborn. Work on Blue Streak as a military project was stopped over a year ago, and during that year we have had to listen to a stream of successive ministerial promises that a decision as to its use for space research would be reached within a few weeks. Yet nothing has happened, and while we wait for a decision the expenditure on Blue Streak continues at about 50% of what it was before the cancellation, while little work is being done and the remaining technical staff grow more and more demoralized.

It is true that the Minister of Aviation has worked hard on the plan for a European launcher, which would utilize the Spadeadam test facilities, the Woomera launching site and the experience gained in developing Blue Streak, even if the present vehicle was totally abandoned. But the weeks continue to drag by as we wait to learn whether other European nations will support the plan or not. Most of them seem to be going to base their decision on that of Germany (allocated the third largest part in the team), and Germany is being very slow in making up its mind.

We are solidly behind Mr. Thorneycroft in his efforts to bring about formation of this European launcher group, but surely even more initiative is required. Britain should announce that it is going ahead with the development of a launcher, come what may. The other countries would be more interested in joining an active, going concern. We should certainly not be alone if we did this: France is already committed to a launcher plan, though with some reservations about the technical details.

To all our British members we therefore say: Have *you* reached an opinion about the desirability of a British space programme? If so, what have you done about it?

Whatever your opinion, may we suggest you do more about it. Write to your M.P. and tell him what you think. Write to at least one national newspaper and tell them. Write to at least one local newspaper. Write to TV and the radio. Tell your boss, tell your friends, tell everyone. Don't be asleep, don't be dead, DO SOMETHING, DO IT NOW.

G. V. E. THOMPSON.

SOME PROBLEMS ENCOUNTERED IN THE DESIGN OF LARGE ROCKET ENGINE TEST BEDS*

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(Communication from British Oxygen Wimpey Ltd.)

ABSTRACT

The main requirements of a typical rocket engine test installation are outlined and illustrations of British and American stands are given. The problem of deflecting a high-speed jet at a speed of 8000–10,000 ft./sec. and a temperature of 5000–6000° F. (2760–3320° C.) is discussed. Methods of measuring thrust are illustrated. Difficulties arising from low temperature and from contamination during erection are also touched upon.

I. INTRODUCTION

MUCH has been written on the subject of space travel, rockets, and the relevant propellents, but very little has been published on the test facilities required for rocket development. The object of this paper is to outline some of the plant employed on a typical test site and so illustrate the kind of engineering problem met with in this type of work. Before an engine can be put on test all the components must be developed separately to ensure reliability and each part must have a short trial run before assembly in an engine. In this paper we will omit discussion on the type of apparatus required for testing individual components and will concentrate on the complete engine test bed.

Most large rocket engines at the present time employ two liquid propellents, one being a fuel and the other an oxidant. Many combinations have been used, but by far the most common is liquid oxygen in combination with a hydrocarbon such as kerosene.

The liquids are stored in separate containers and a small feed is taken to a unit known as the gas generator, where ignition takes place, and the hot gases are used to drive a gas turbine to which are coupled two main pumps, one for oxidant and one for fuel. The pumps feed the liquids into the rocket thrust chamber where combustion takes place and the exhaust gases emitted at high velocity produce the required thrust.

1. THE ENGINE IN RELATION TO THE FLIGHT VEHICLE

Most large rockets are driven by two or more engines. Fig. 1 shows some of the ways in which these can be arranged. Steering may be either by gimballing the engines or by using small vernier motors.

In order to lift the rocket and impart an acceleration to it, the combined thrust of the engines must be greater than the weight of the rocket with a full propellent load on board. An engine test facility in which the engine is anchored and fired must, therefore, be capable of standing a very high thrust. Provision may be made for testing single engines or clusters arranged as they would be in the flight vehicle.

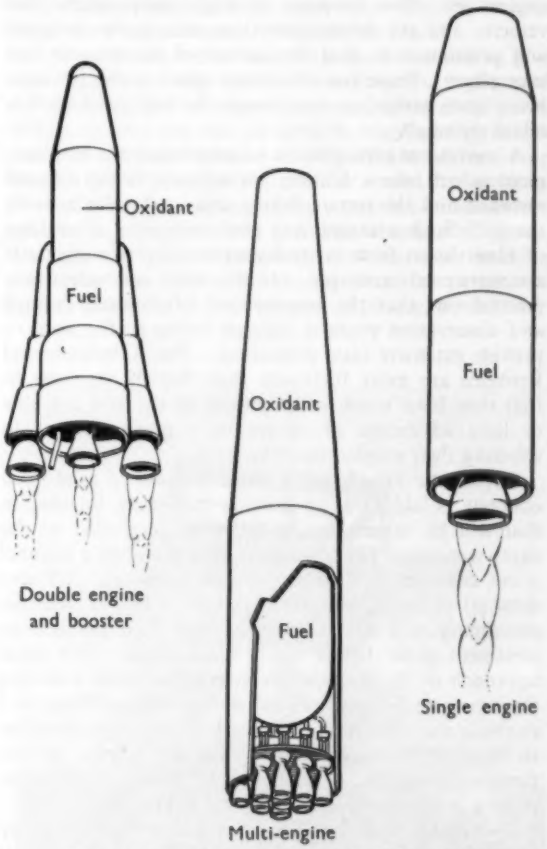

FIG. 1. Arrangement of engines in flight vehicles.

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II. TEST STAND

The rocket engine assembly is tested under working conditions in an emplacement generally referred to as the test stand. It is impossible for personnel to be situated close to the engine during firing, and complete remote control with adequate means of observation from a distance is essential. In order to minimise hazard and damage in event of accident, the propellent stores, pump houses and services to the test stand are all situated at a safe distance from the firing area. The engine jet efflux emerges at high temperature and velocity and the emplacement requires to be designed and positioned so that dissipation of the exhaust can take place. These considerations result in the test area being quite extensive even though the test stand itself is relatively small.

A convenient arrangement is that wherein the emplacement is cut into a hillside, the exhaust being directed outward and the terrain falling away naturally beneath the jet. Such a situation is also convenient since lines of observation from control centre and observing posts are more easily arranged. In this latter connection it is pointed out that the employment of elevated control and observation posts is difficult owing to the need to provide extensive blast protection. The Americans and Russians are more fortunate than British engineers in that they have much wider choice of site and are able to take advantage of nature to a greater extent in selecting their emplacement location.

Within the hillside cut a suitable mass of reinforced concrete is laid so as to provide the strong foundation that will be subject to the full load developed by the captive engine. Leading away down the slope a channel is cut and concreted to provide the flameway. Effluent disposal channels lead from this to a lagoon wherein contaminated water is collected and then pumped to treatment plant before being recirculated. The main approach to the test stand is at a higher level, reducing the amount of lifting needed during engine fitting and enabling the more important work of engine preparation to be effected conveniently. Thus the exhaust jet and flame are dealt with in the basement, as it were, the more refined activities being on the first floor.

The rocket engine is hung from a structure built up from the main concrete base. In order to simulate conditions pertaining during rocket launch and flight, the engine is arranged to fire vertically downward and may, in addition, be gimballed as in flight vehicle steering. Means of preventing erosion of the stand base and burning of adjacent installations by the exhaust jet are essential unless a very long flame drop can be arranged, and the test stand cantilever mounted over the drop.

Various configurations of test emplacement are employed. Fig. 2 shows a typical vertical type of stand: the propellent tanks are mounted above the engine in missile configuration. Such tank mounting, although necessitating a tower of considerable height,

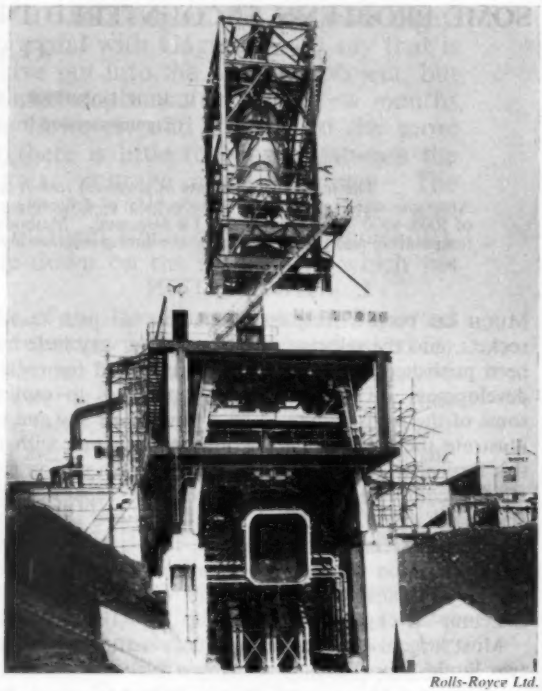

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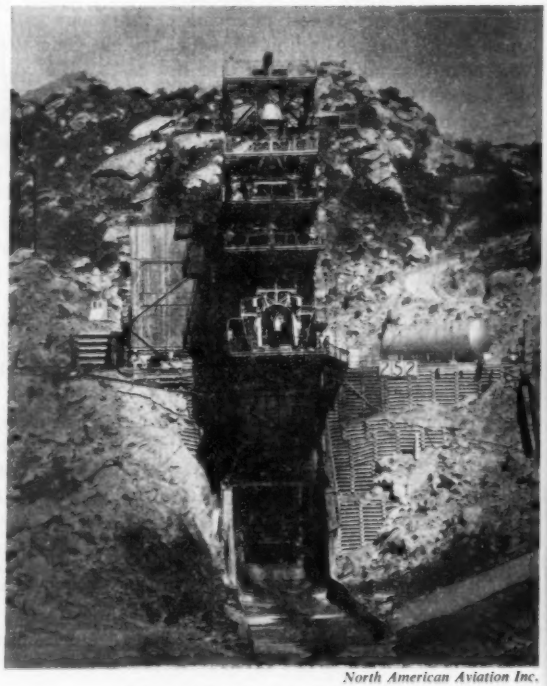
FIG. 2. Typical vertical engine test stand (Spadeadam Rocket Establishment).



North American Aviation Inc.

FIG. 3. Early American test stand.

has the advantage of removing the problem of mounting bulky vessels away from the lines of vision.

Fig. 3 shows an early type of American test stand. This consists of a heavy (and expensive) steel structure in which the engine to be tested is mounted on a cantilever slung out from the main structure. Since the thrust of a single engine would be in excess of 50 tons, the structure requires to be very strong.

Fig. 4 shows an American design of stand in which structural steelwork for tank supports has been reduced to a minimum. This type of stand is possible in a climate such as that of California but not desirable in the British climate—it is not ideal to have to climb vertical cat ladders for access to the tops of tanks during wet weather.

In addition, powerful mobile cranes of high lift must be available for erection of the tanks and for changing them when necessary.

Fig. 5 shows a test stand under construction. The steelwork is of very heavy construction in order to withstand the heavy loads placed upon it during engine firing. The propellent tanks are not yet mounted.

It will be noted that each test stand caters for one test bay only and is situated quite remote from any other test bed. This is done in order to reduce the damage resulting from accident. There is obvious economy, however, in building a single structure to accommodate two or more test bays. This has, in fact, been risked in the U.S.A., but there is no doubt that it is a somewhat chancy business for, although it is possible to isolate minor incidents by providing blast screens, etc., there is a consequent loss of clear vision lines. Further, a minor accident on one bay can mean several days' repair work during which time the rest of the stand is inoperative. Engine test stands are extremely expensive installations and once built, every effort is made to keep them in commission and working full time.

It is necessary when designing the test stand to give consideration to the work of installing the engine and the carrying out of adjustment, etc., after installation. Whilst engines are not particularly heavy, being in the order of a couple of tons or so inclusive of mounting frame, they do require particular care in handling. Furthermore, it is necessary that installation should be effected in minimum time and with absolute efficiency. To this end engine handling facilities and working platforms for personnel should form a permanent feature of the stand. There are, of course, a multitude

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FIG. 4. Test stand with minimum structure.

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FIG. 5. Test stand under construction.

of techniques and devices that may be employed for engine handling. A very popular technique involves the use of a sliding platform which is on rails running from a point beneath the engine installed position to a position out on the approach apron. The engine is loaded by cantilevered hoist block onto the platform in the out position. The platform and engine are then run in so that the engine is immediately beneath its fixing point. The final small movements required for engine fixing are catered for either by incorporating hingeing and jacking movements in the engine-carrying jig itself or by embodying similar features in the sliding platform. Some sliding platforms are quite complex units, being powered by air motors (thus avoiding flameproofing and trailing leads) and having forward, backward, up, down and tilt movements in three planes. On the other hand a simple, hand-powered, frame platform may be employed in conjunction with an engine-handling jig or dolly, the latter being hydraulically powered.

Platforms for work around the engine require to be removable since they would restrict viewing, etc., if left in position during firing. Popular practice is to employ elevating platforms that can be positioned at any required level easily, and when not required can be tilted to the vertical. Such a platform can be seen on the first deck in Fig. 2.

The sliding platform provides a convenient means of covering the flame opening during firing periods and thereby removing a considerable hazard and inconvenience to personnel.

The popular elevating/tilting maintenance platform does tend to become a somewhat cumbersome affair and whilst it is quite efficient functionally, it is our opinion that neater and more convenient arrangements are possible by careful combination of fixed, hinged and partially elevating structures. It must be said, however, that there is need for very close collaboration between the stand designer and the engine test engineer in effecting the best possible arrangements.

There is but limited time to deal with the more detailed aspects of design but one or two items are presented as being illustrative of the type of engineering problem that is met with in this class of work.

Consider the requirement to deflect the engine exhaust jet through 90° in order that it may be dissipated conveniently into the air. The deflecting surface demands careful design and efficient cooling in order that it may serve for many tests—the cost of continual replacement would be prohibitive both in time and in money.

A typical large rocket engine might have an exhaust nozzle of, say, 36-in. diameter emitting a jet with a velocity of about 8000–10,000 ft./sec., at a stagnation temperature of 5000–6000° F. (2760–3320° C.). The deflector must be capable of withstanding the sudden application of load and thermal shock. The conditions can be appreciated from a study of Fig. 6, which shows an engine firing.

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FIG. 6. Test firing.

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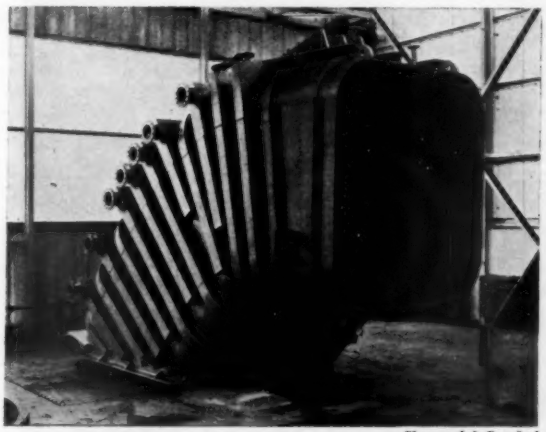
FIG. 7. Water-film-cooled flame deflector.



Sheppard & Son Ltd.

FIG. 8. Flame deflector under construction.

The water-film-cooled deflector (Fig. 7—8) has been found to be the most reliable approach to the problem to date. Essentially, this deflector consists of a steel plate over which a continual film of water is maintained to such good effect that the temperature of the steel plate rarely exceeds 200° F. (93° C.) or so. The need for protecting the sides and overhead portion of the installation, especially when the engine is gimballed, results in sides and top being added to the deflecting plate so that the whole resembles a large steel elbow. Cooling water is conveyed to the rear of the deflecting surface by a series of channels which also serve to strengthen the structure mechanically. Holes drilled through the plate allow water from the channels to flow on to the deflector surface. The mounting of the elbow must allow for thermal expansion and must transmit the shock loads and steady running load. Trunnion mounting in conjunction with swivel link offers a reasonable mounting technique. Water pipes require to be attached via some form of flexible coupling.

Space does not permit more detailed consideration of design but it may be stated that empirical formulae are largely used for water quantity and distribution determination—inevitably adjustment is required and quite often a number of firings are required before satisfactory performance is achieved.

There is undoubtedly room for improvement upon the current practice of flame deflection and as facility engineering becomes more advanced, we shall doubtless see new techniques employed. It may be of interest to mention some of the approaches that have already been tried even if with somewhat indifferent results:

(1) Deflecting surface made up of tubes through which water circulated (Germany). This type has a poor life and is only suitable for small engines.

(2) Direct jet cooling: water injected into the flame before reaching the deflector (U.S.A.). This requires a longer flame drop and careful positioning of the jets, the results are erratic and there are unexplained hot spots.

(3) Use of a vertical exhaust with a very long flame drop—80 ft. or so has been employed in U.S.A. where the terrain is favourable. Considerable erosion is encountered.

(4) Water pool with discharge direct into the pond. The useless water simply blows away.

(5) Refractory or concrete uncooled. This requires a long drop, there is rapid erosion, and repair after each firing is necessary.

Control and observation of the test firing is effected from a control house situated at a more comfortable distance from the test stand. Viewing is provided for by episcopes, periscopes, black-and-white and colour television. High-speed photography is also extensively employed. No effort is spared to provide first-class viewing facilities, for following upon sighting of a failure of any portion of the rig extremely rapid cut-off must be effected if extensive damage and explosion are to be avoided. Such viewing requirements have their effect upon the general layout of the stand in that it is necessary to avoid obscuring lines of vision and provision of an extensive lighting system becomes essential. Lighting for television and photographic cameras must, of course, remain on during the actual firing when there is extensive vibration present. One of the problems facing the illuminating engineer lies in the design of anti-vibration mountings for the lamps. The vibrations are of complex nature and a good deal of experiment is required before satisfactory life can be obtained from the lamps.

Propellent feeds to the engine are required to approximate those conditions which pertain when the unit is mounted in the flight vehicle. Thus the propellent tanks require to be mounted close to the engine with connecting lines as short and as straight as possible. The tanks are permanently piped to bulk storage and pumping stations situated at a safe distance from the test emplacement. It will be appreciated that in firing for one or two minutes, the rocket engine consumes a considerable quantity of propellents, hence the tanks and pipework are of large size. The propellent vessels are pressurized with gaseous nitrogen piped to the stand from a remote high-pressure storage battery. The incoming nitrogen lines feed a Pneumatic Control Panel, from which point gas supplies are distributed to vessels, gas-operated control valves, purge points, etc., after pressure has been regulated to the required value (Fig. 9).

North American Aviation Inc.

FIG. 9. Pneumatic control panel.

The instrumentation required for engine testing is of course an extremely important portion of the installation and represents a considerable percentage of the total plant cost. To enter into detailed description of the instrumentation is not within the scope of this paper, but it would be misleading not to give some indication of the magnitude of this fundamentally important aspect. A typical test set up for a single test stand requires independent instrumentation for some sixty pressure points, thirty or so temperature points, ten to twenty flow points, about a dozen vibration sources, thrust measurement, level measurement, revolution

counters, etc. Additionally there are complex intercommunication systems with head sets, listening posts and transmitting stations. Almost all large valves in the propellent and pressurizing circuits are remotely controlled.

Often an underground cable duct carries the control and instrument cables from an engine test emplacement to the control room. Such a duct might be some 6–7 ft. square and carry some 6000 or so cables (Fig. 10).

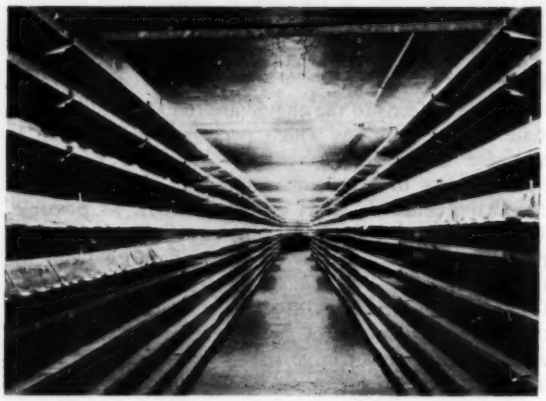


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FIG. 10. Control and instrument cables in duct (Spadeadam Rocket Establishment).

Control cables are positioned away from the instrument cables to avoid interference.

Periscopes within the control room are directed on the test emplacement to provide direct viewing and television is also usual (Fig. 11).

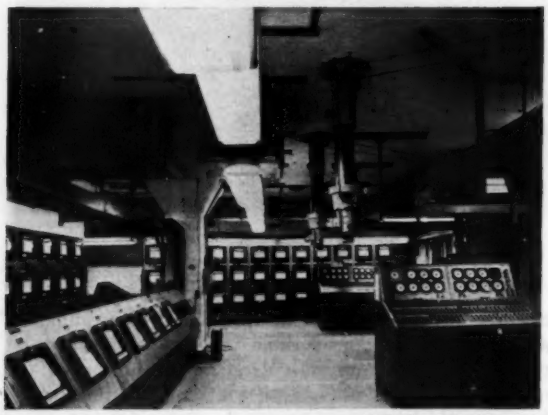

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FIG. 11. Control room, showing periscopes (Spadeadam Rocket Establishment).

In addition to items directly concerned with the firing of the engine a large amount of auxiliary equipment is employed in preparing for the test and in general maintenance work. Cranes, lifts, moving platforms, hoists, cleaning plant, heating and ventilating equipment, etc., are examples of such auxiliary services. Warning systems and other safety precautions also form an important part of the installation. It is usual to group the electrical distribution boards and switchgear at a point called the Electrical Control Station, which is often a small building at the side of the emplacement. The whole of the electrical equipment on the test stand proper is required to be flameproof. Equipment within the electrical control station may be flameproof or, alternatively, the building may be pressurized.

Floodlighting is employed for television. Colour and black-and-white television lighting requirement amounts to something like 30 kW. per stand. Some of the lights are mounted on towers standing away from the test stand proper. Emergency lighting usually is of the automatic type powered from batteries located in the Electric Control Station.

Fire-fighting facilities are an extremely important part of the installation. Those systems which apply water in finely divided droplets are most favoured. Rings of nozzles are situated about the engine thrust chamber, the turbopumps and the propellent vessels. The systems are remotely operated from the control room but are arranged to fail wet in event of control failure. Hydrants and monitor nozzles are sited at strategic points around the emplacement.

III. THRUST MEASUREMENT

A very necessary item required in development and proving the rocket engine is the measurement of the thrust. It is to be appreciated that not only is it necessary to determine the magnitude of the thrust but also its line of action relative to the main axis of the thrust chamber. Once the characteristics of a particular thrust chamber have been determined there is, however, no need to repeat all the measurements that are made to find thrust vector displacement and subsequent measurements are usually only concerned with thrust magnitude along the main axis. Thus we find two types of thrust measuring equipment: one a simple assembly, designed to measure thrust along the main axis, and the second a more complicated set-up designed to measure not only the main axial thrust, but also the vector displacement and angularity misalignment.

The simple arrangement is shown in Fig. 12.

Within the test stand the engine is hung from a large steel frame known as the thrust transition frame. Immediately below the transition frame is mounted the main beam of the thrust-measuring frame. This is arranged to carry a special load cell for the measurement of thrust, together with various hangers, brackets and supports for rocket engine components, such as the turbo-pump mountings and the footings for the pitch and yaw jacks that effect engine movements. The gimbal block carrying the thrust chamber is mounted immediately below the measuring load cell so that the latter is sandwiched between the thrust source and

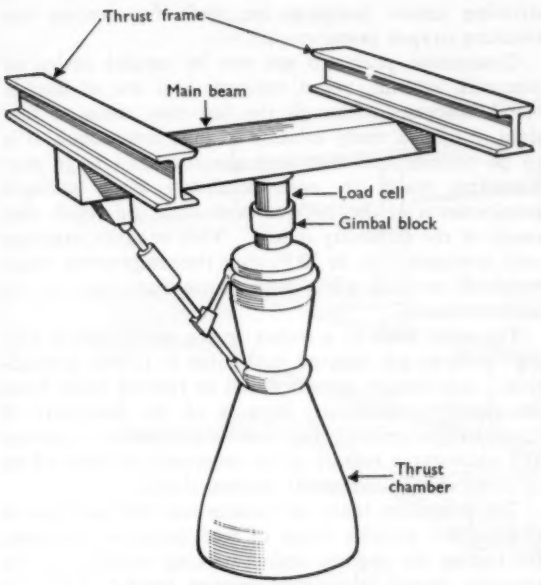


FIG. 12. Simple thrust measurement.

the thrust transition frame. When the engine is fired the resulting thrust compresses the load cell and the resulting dimensional change is measured and translated in terms of thrust in pounds. Thus in essence the scheme is very simple but success is dependent on the assembly being extremely rigid and free from any major deflection.

A more involved assembly (Fig. 13) is required when side loads have to be measured.

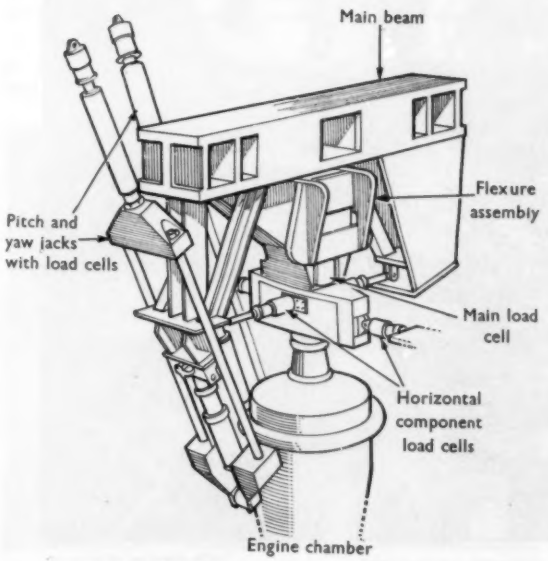


FIG. 13. Thrust vector measuring rig.

The set-up for measurement of main axial thrust is similar to that just described, excepting that a system of flexures is included between the main load cell and the thrust beam. The flexures are designed so as to permit horizontal movement, which is, however, restrained by two members at right angles, each incorporating a load cell. Normal angular movement of the rocket engine is effected by two actuator jacks operating so as to turn the thrust chamber about the gimbal block. For thrust-measuring purposes, these jacking arms are fitted with load cells. The basic set-up thus consists of five load cells, one main thrust cell, two horizontally mounted units and a cell in each gimbal jack arm.

Readings of all five cells are taken with the engine firing centrally downward. The actuator jacks are operated to effect rotation of the thrust chamber through the mean position and all load cell readings recorded. From these readings displacement and angular components of misalignment are calculated.

There are, of course, other methods employed for measurement of thrust; the method described, however, illustrates the general nature of the problem. Most of the difficulties encountered in the design of such equipment arise from the need to provide a very strong and rigid assembly within a restricted space (Fig. 13).

The components of the rocket engines are required to be small, light and compact, but they are not called upon to give long life. The thrust-measuring equipment on the other hand is required to do almost exactly the opposite; it must be very rigid and strong and provide a long, useful life. When the two are brought together some rather incongruous situations are likely to arise; in fact one might see, for example, four 1-in. bolts holding one portion of the unit to which is attached a portion of the engine proper, the attachment being three $\frac{5}{16}$-in. bolts.

No mention has been made of the calibration of the load cells in order to simplify the description. It is in fact very necessary to arrange for calibration in the design, and each load cell requires to be matched to a calibrating cell and the whole system is thereby enlarged and complicated.

IV. LOW-TEMPERATURE COMPONENTS

Liquid oxygen boils at a temperature of the order of −183° C. at atmospheric pressure. At such a low temperature some materials, including mild steel, become very brittle and have negligible shock resistance. The working temperature range required of most components on liquid oxygen duty is from ambient to about −190°C., hence the problem of dimensional change due to contraction is very real. Since working temperatures are so very much below freezing point, condensation and icing are factors which must be taken into account at the design stage. Many organic materials and some inorganics form explosive gels in the presence of liquid oxygen, hence the use of ordinary lubricating oils is not

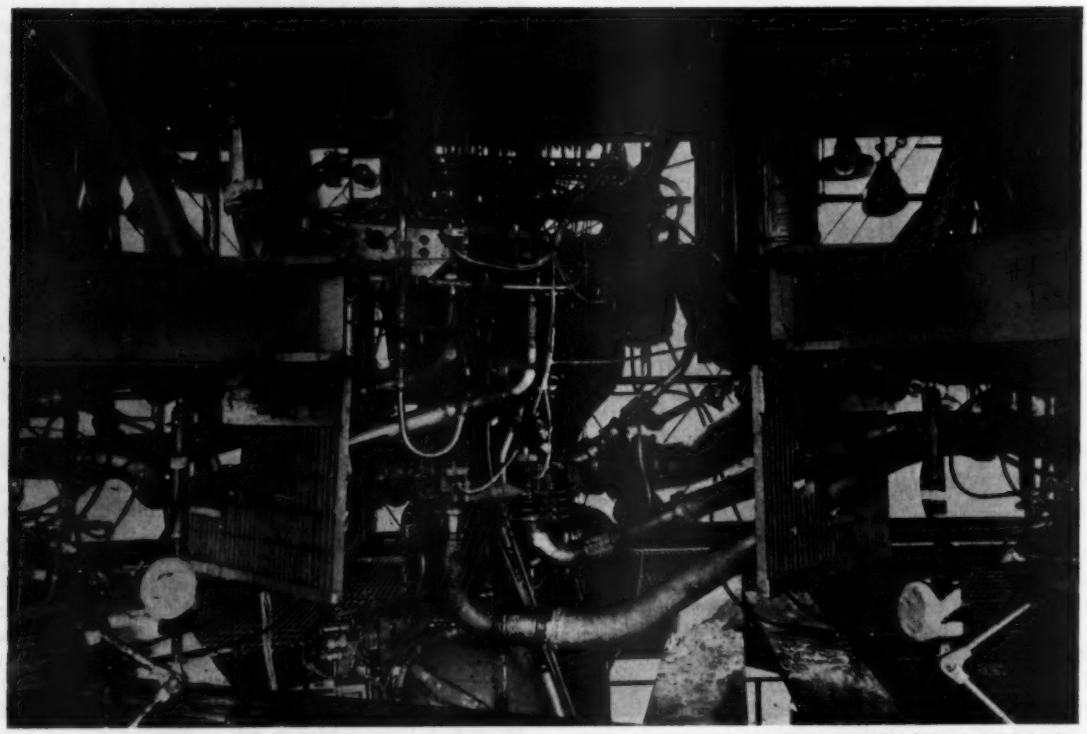
permissible and considerable care has to be exercised in the choice of gaskets, jointing compounds, shaft packings, seals, etc. Whilst oxygen itself does not burn, it is a great supporter of combustion, and almost anything will burn readily in its presence. On exposure at ambient temperature and pressure the liquid boils very rapidly and if splashed on the skin can cause nasty burns.

The design of tanks, vessels, valves, pumps and pipework systems for the handling of liquid oxygen thus becomes a rather specialized business with many pitfalls for the unwary. Austentitic steels, aluminium, copper and its alloys, are the metals most useful to the low-temperature engineer. Stainless steel of the 18/8 variety is perhaps the most favoured, for apart from its cost, it offers the advantages of good strength and impact resistance, freedom from corrosion, machinability, good welding properties, and low thermal conductivity. The stringent cleanliness requirements peculiar to rocket engineering make the use of stainless steel particularly attractive on the clean side of the test stand filters. Since liquid oxygen boils below ambient temperature it is important to avoid trapping liquid in a section of the system that is subsequently allowed to return to ambient conditions. Under such circumstances the very large increase in internal pressure would result in severe overstressing unless provision be made for venting the resulting oxygen gases.

Contraction problems are met by careful design of pipework systems, vessel supports and use of flexible metal bellows. Although the last may seem at first sight to offer a ready solution to pipe contraction, it is to be remembered that high pressure and large pipe diameters result in correspondingly large strength requirements at the bellows wall with the result that much of the flexibility is lost. Very roughly, stainless steel contracts 1 in. in 30 ft. over the temperature range involved, so that quite large movements have to be accommodated.

The main feeds to a rocket engine are shown in Fig. 15. Bellows are inserted in the line to permit contraction. Anchorages are employed to remove loads from the pump connections. Because of the possibility of liquid oxygen spillage, key structural members, supports and anchorages require to be protected or designed so as to be able to withstand thermal shock.

The propellent tanks are pressurized with nitrogen to provide the variable range of feed pressures necessary for testing the engines under working conditions. As pressure vessels, the tanks require careful design in accordance with recognized codes of practice.



North American Aviation Inc.

FIG. 14. Piping and wiring around engine.

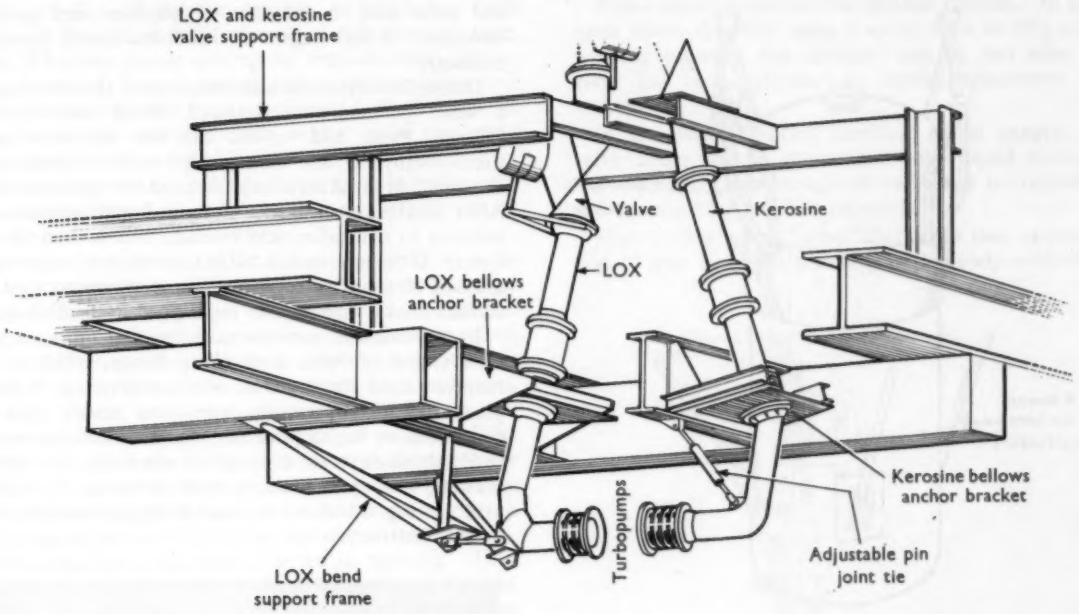


FIG. 15. Feed pipes to engine.

For certain series of tests an engine thrust chamber may be tested on its own without using the turbo-pumps. For such a case it is necessary to feed the liquids to the thrust chamber at higher pressure and rate, thus the propellent tanks require to be of much stronger construction.

Spheres are frequently used, often at considerable pressures; a typical instance being a sphere which has an internal diameter of 10 ft. and is $2\frac{3}{4}$-in. thick. Fig. 16 shows a sphere in course of manufacture. Since this is constructed of stainless steel, unusual welding difficulties arise demanding the use of special techniques.

Ashmore Benson Pease Ltd.

FIG. 16. Stainless steel sphere under construction.

It is usual to provide the tanks with bursting discs, safety valves, anti-vortex devices, etc.

The propellent tanks are quite heavy, often weighing 50 or 60 tons. As the kerosene is at atmospheric temperature, no special difficulties arise in connection with the support of the tank.

The liquid oxygen tank, however, raises problems both in the necessity for providing for contraction of the vessel, and preventing low temperature from reaching the mild steel supporting structure where great danger would arise from embrittlement.

The vessel can be supported on feet with thick pads of insulation between the feet and the mild steel supports, and provision made for some of the legs to be free to slide on contraction of the tank. A second method is to hand the vessel on a number of long stainless steel bolts and adjustment of the nuts can be made to get an even load at all the support points. A similar method is shown in Fig. 17. The double toggle arrangement permits adjustment to be made.

In order to ensure even distribution of stress, strain gauges are attached to the support points and the toggles adjusted to give uniform readings on the strain gauges while the tank is filled in progressive steps. Tie rods are accurately placed so that their length remains constant during both diametrical and longitudinal contraction of the vessel.

In the vertical test stand arrangment there is considerable movement between the loaded position (*i.e.*, tanks full) and empty unloaded position and due allowance must be made in the piping connections for this

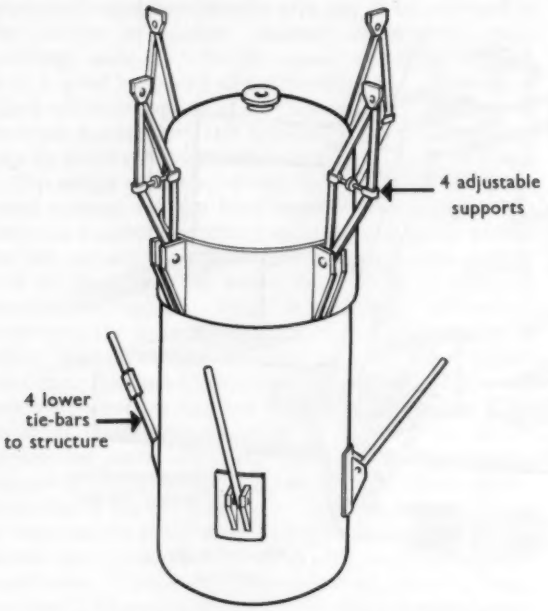


FIG. 17. Toggle supports for LOX vessel.

dimensional change. Often the vessel mounting arrangements include load cells, so as to provide indication of contents. Such indications may be either additional to or in lieu of other forms of level measurement.

V. CLEANLINESS

At this stage it is necessary to refer to the important subject of cleanliness. Dirt and grit can prove to be a serious hazard on two counts.

First of all a valve may be prevented from closing completely and flow of fluid may persist after it should have been cut off. This could result in extensive damage to the engine and test installation.

Secondly, traces of hydrocarbon can cause a severe explosion if brought in contact with liquid oxygen. Metallic particles, when lodged on the feed of an oxygen valve, can also cause an explosion if subject to impact —such as the rapid closing of a valve.

Many failures of rocket experiments are due to the presence of foreign bodies in the system. On this account very elaborate steps are taken to maintain all surfaces which are to be in contact with propellents in a state of surgical cleanliness. On the supply system for each of the main services and as close as possible to each facility, an efficient filter is fitted. After this point all contact surfaces are usually in stainless steel and the highest category of cleanliness is observed. Before the filters it is not necessary to use stainless steel and a material compatible with the fluid is used; this may be copper or aluminium in the case of liquid oxygen, and mild steel in the case of kerosene and gaseous nitrogen. A high degree of cleanliness is still, however, necessary.

During construction and erection of the test facility a strict procedure is followed, being somewhat as follows: Pipes and vessels are first degreased with trichloroethylene and then pickled with a suitable acid mixture. Hydrofluoric acid is used for stainless steel. After pickling, the surface is treated with caustic soda solution to neutralize acid residues and is then washed clean. If the tap water is liable to contain an appreciable amount of solids in solution it is necessary to wipe the surface finally with a clean rag dipped in distilled water.

Each section of pipe or each opening on a vessel is then sealed off with a blanking flange, which is not removed until the moment when piping up is taking place. Piping operations are done under dust-free conditions as far as possible. Such conditions are not easily obtained on the average test site which, for obvious reasons, is in open country, often of barren, wind-swept aspect. Fig. 18 shows a concrete type of engine stand under construction.

Rolls-Royce Ltd.

FIG. 18. Test stand under construction (Spadeadam Rocket Research Establishment).

During piping-up the area is enclosed with polythene sheeting. Operators must wear clean white overalls, rubber shoes and clean lint-free gloves. Entry into the enclosed space is restricted to essential visits.

Each piece of pipe or component which has been cleaned is marked with a band of red adhesive tape, and if for any reason subsequent contamination occurs, the tape is at once removed and is not replaced until the component has been re-cleaned. Pipes may be pickled at the manufacturer's works, or in the tanks provided for this purpose on the test site.

Valves and other components to go in pipelines are cleaned and tested on site in an establishment known as the Equipment Test Laboratory.

A valve, on receipt in the laboratory, whether it be new or returned out of service, has a work test card opened for it. It is then subjected to a hydrostatic test, usually employing one-and-a-half times working pressure. In the case of certain diaphragm valves, this test has to be waived to avoid damage to the diaphragm. In such a case, a hydraulic test on the body is made. After the hydraulic test, the mechanical portions of the valve are completely stripped down and the parts are subjected to a visual examination, the result being recorded on the work test card. Any repairs, rework or fitting of new seals is carried out at this stage.

The metal parts are then subjected to cleaning. They are first washed in paraffin to remove superficial dirt and grease. If necessary (*e.g.*, in the case of castings or welded parts), an acid pickle is given, followed by washing, neutralizing and drying. The parts are then put in a trichlorethylene vapour degreaser and cleaning also supplemented by liquid spraying.

Before re-assembly, sliding surfaces are lubricated. Very great care is necessary and on no account can hydrocarbon oils be used. Special lubricants have been developed for use with liquid oxygen and kerosene. Some of the former incorporate molybdenum disulphide.

The valves are then re-assembled by operators wearing clean gloves. Finally, functional tests are carried out. These include check of the operating mechanism in the case of remotely controlled valves. Valves which will operate with liquid oxygen are tested under cold conditions with liquid nitrogen for satisfactory opening and closing, and for leakages.

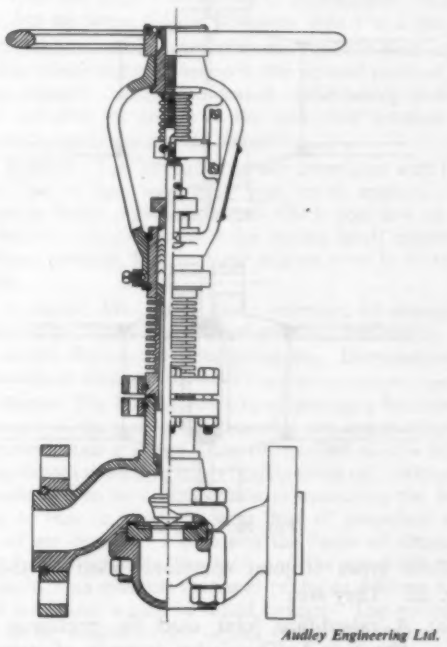
Leakage through valves is a big problem where fuels and oxidants are concerned, being wasteful, inconvenient and often dangerous. Where gaseous nitrogen is involved, the loss through valves can easily dominate the situation and if uncontrolled could disperse the entire output of the storage and manufacturing plant. For this reason the problem requires careful study. With care in making pipe joints, leakage from this source can be kept negligible and the major part of measurable loss confined to valves.

An arbitrary proportion of about 5% of the gaseous nitrogen production is taken and on this basis the maximum leakage acceptable from a valve can be determined. Such leakage rates should be obtainable without great difficulty on the majority of valves and those falling outside the permissible allowance are generally capable of correction.

Relief valves consistute the greatest trouble. In most cases where the relief valve is set to blow at 10% above working pressure, the standard can be met after the valve has been subjected to careful adjustment and correction.

In the case of valves handling liquid oxygen, the valve under test is pressurized with liquid nitrogen. Any liquid seeping through the valve seat is evaporated and the resulting gas flow measured.

High-quality globe valves similar to that shown in Fig. 19 may be either manually or remotely controlled.



Audley Engineering Ltd.

FIG. 19. High-quality globe valve.

Test on these valves is made with water and with gas at atmospheric temperature and no loss is permitted.

Commercial-type wedge-gate and globe valves are used at certain points on the liquid oxygen system where less stringent leakage rates may be accepted, and the permissible leakage rates are adjusted in accordance with the valve size.

VI. PIPES AND JOINTS

As previously mentioned, in the section downstream of the final filters all contact metal is stainless steel, usually austenitic steel stabilized with titanium. The flanges are welded on using an electrode stabilized with niobium, as is normal.

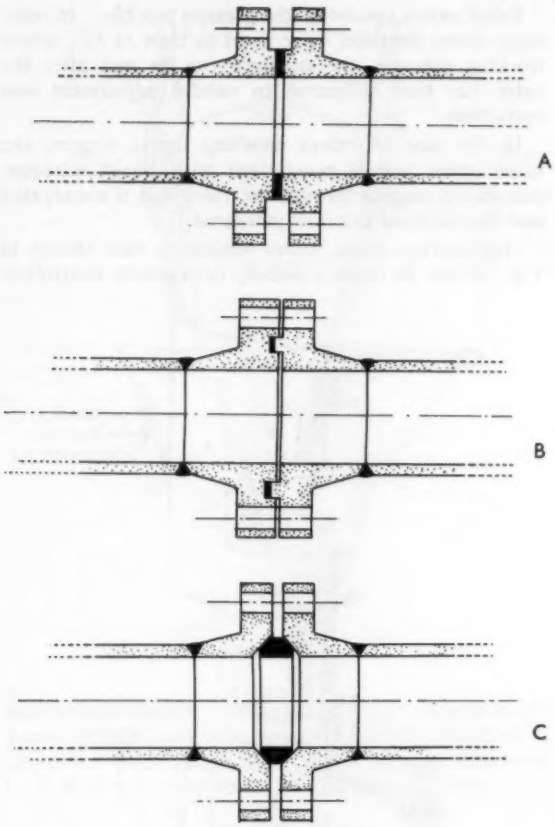


FIG. 20. Pipe joints.

Three types of joint commonly used as shown in Fig. 20. They are:

(*a*) A raised-face joint used for pressures up to 400 lb./in.^{2} The gasket is made of compressed asbestos fibre. It is most essential to keep a clean cut on the inner edge so that particles do not become detached into the system and so cause a hazard.

(*b*) For pressure between 400 and 1000 lb./in.^{2} a fully trapped joint is used for liquid oxygen and gaseous nitrogen, this being known as the *large tongue and groove joint* in B.S.1560. A compressed asbestos fibre gasket gives excellent service, but the joint may require occasional tightening.

(*c*) For gaseous nitrogen at pressures above 1,500 lb./in.^{2}, a *lens ring joint* is often used. This forms an excellent seal providing it is carefully assembled under clean conditions. The lens ring joint has been used extensively for high-pressure nitrogen distribution lines; often there is between five and six miles of piping carrying gas at a pressure of about 3,500 lb./in.^{2} For cleaning and inspection purposes it is necessary to provide a joint every sixty feet or so. The flange is in mild steel, the ring is in a harder carbon steel and is cadmium-plated. Such a joint has proved very satisfactory and no measurable loss has been experienced which could be traced to leakages at these joints in the whole of a very large system.

VII. CONCLUSION

It is hoped that within this short paper some conception of the nature of test facility work as distinct from work on the rocket itself will have been gained. This is a comparatively new branch of engineering embracing many different fields; almost every branch of civil, mechanical and electrical engineering finds application on the rocket test site.

ACKNOWLEDGEMENTS

Our thanks are due to the Ministry of Works and Ministry of Aviation for graciously permitting this paper to be presented. British Oxygen Wimpey Ltd. were the main contractors for the construction of the Spadeadam Rocket Research Establishment in Cumberland and the Directors kindly gave their assent to presentation and publication of the paper. Rocket engineers from Rolls-Royce Ltd. and de Havilland Ltd. have been most helpful in the gathering of material, and some of the photographs were kindly provided by Rolls-Royce Ltd. Many of the illustrations are from photographs by North American Aviation Inc. of U.S.A.; this company is possibly the foremost in the world in the field of rocket engine test facilities. We are particularly indebted to N.A.A. for not only these photographs but for the whole background of modern rocket facility engineering provided by this great corporation. Messrs. Pye Ltd., who were the main instrument sub-contractors for Spadeadam, provided assistance and other manufacturers also kindly provided photographs of equipment which they manufactured.

DISCUSSION

The Chairman, Dr. L. R. SHEPHERD,* B.Sc., Ph.D. (Chairman of Council): I thank the Institution of Plant Engineers sincerely for asking me to represent the British Interplanetary Society by taking the chair at this evening's meeting. It is a very great privilege for me to have been asked to do so.

I think everyone is aware of the enormous developments that have gone on in rocket propulsion in the last few years and in the construction and launching of large rocket vehicles. The development of these vehicles has required the development of large engines developing considerable thrust, and one of the most expensive and difficult items in this development is the testing on the ground of the rocket engines. This is a subject which is responsible for quite a considerable amount of expenditure of effort and money, and it is one of the most important aspects of the whole business.

We are particularly privileged tonight to have here from British Oxygen Wimpey, Mr. Forster, the Chief Engineer, and Mr. Breen, the Senior Engineer, who have considerable experience in this matter. British Oxygen Wimpey, as you probably know, has been responsible to the Ministry of Works as the main contractor for the construction of the Spadeadam testing facilities where, among other things, the big engines in Blue Streak will be tested.

Without further ado, I ask Mr. Forster and Mr. Breen to tell us something about the problems in the design of large rocket engine test beds.

The paper was then presented by Mr. Forster and Mr. Breen.

The Chairman: Thank you very much, Mr. Forster and Mr. Breen. You have, I am sure, conveyed to all the audience—you certainly have to me—some impression of the considerable complication which arises in just the testing of engines. I have found it fascinating to consider the type of your engineering and test facility compared with the flimsy engineering of the actual engines, tanks and so on of the rockets—particularly the containers for the liquid oxygen.

Mr. LENNOX-NAPIER†: Mr. Forster, in his very interesting summary, touched on the question of low-temperature embrittlement of mild steel, and Mr. Breen said a little more about it. I should like to ask the lecturers to expand a little on the means of protecting the primary structure of the test stand, which is presumably not in austenitic steel, from the effect of oxygen spillage in an accident, when large quantities of liquid oxygen may spray over the metal framework while it is heavily loaded, with some risk of embrittlement fracture and total collapse. Perhaps we could be given some idea of how this calamity is avoided.

Mr. FORSTER: First of all, the immediate supports for the engine are in austenitic steel. The deflector itself is arranged to have a water film over it all the time when spillage is likely to take place, so that it is protected. The supports for the tanks and so on are in austenitic steel up to the main structure, and at that point very often a duplicate arrangement is made so that if one series of members fails something else can take the load in addition. But there is no real means of catering for every possibility, and ultimately one is left with a certain amoutnt of risk.

Mr. THAXTER†: I was interested in the suggestion made by Mr. Forster that discharge from the engine into a tank of water had been considered. If the tank was 20 ft. or 30 ft. deep, surely it would have been satisfactory, or would the efflux have pushed the water away?

Mr. BREEN: I think I can answer that question. The experiment was tried in America by North American Aviation. They had quite a deep pond (I cannot recall the exact depth), but the water did not last more than 1 or 2 sec.

The Chairman: One understands the need for multi-access when the rocket engine is tested in the vertical position, but I should imagine that a good deal of useful testing could be carried out with the engine in the horizontal position. Is there much experience in that respect?

Mr. FORSTER: I do not know of any experience with large engines, but it has been tried with small engines. The particularly heavy American stand which you saw on the slides had an attachment on it for testing small engines in an inclined position, but the large engines were to be tested vertically.

Mr. CURRAN: Mr. Breen made reference to measuring the level of the liquid oxygen in the tank. Presumably one has a certain degree of boiling going on. How accurately is it possible to measure the level?

Mr. BREEN: The boiling point is, of course, a function of the pressure of the tank at the time that you are making the measurement, and it is not quite so manifest as one might imagine, though there is certainly boiling going on. Although one would like to be very accurate in measuring the level, one has to bear in mind the large bulk of propellent with which we are dealing. I gave you the figure of about 50 or 60 tons full weight. The tank and the steelwork in it would in such an example represent probably a dozen tons, and the remainder would be liquid oxygen. The boiling is limited to the surface of the liquid, which is quite small in relation to the total bulk. Nevertheless, it is a problem, and that is one of the reasons why load cell or weight measurement is employed as a check or an additional means of measuring the level. I am not an instrumentation engineer but I know that our instrument people have quite a problem with this liquid oxygen measurement, or, indeed, with the measurement of any boiling liquid, but reasonable accuracy is obtained. Perhaps the very fact that load cell or weight measurement is resorted to is indicative of the fact that normal differential gauges or integral transformer measurements do not meet the total requirements.

As regards the precise degree of accuracy that is obtained, I am afraid that I have not got any figures which I could quote off the cuff.

Mr. G. V. E. THOMPSON,‡ B.Sc., B.Sc.(Eng.), A.R.C.S., F.R.I.C. (Fellow): Where aluminium is used, are there any preferred alloys, or is just the pure metal employed?

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† de Havilland Aircraft Co. Ltd.

‡ Senior Information Officer, The British Non-Ferrous Metals Research Association, Euston Street, London, N.W.1.

Mr. FORSTER: There are certain alloys with manganese in them which are used.

Mr. THOMPSON: With 1¼% manganese?

Mr. FORSTER: The British Standard Alloy NP5/6 calls for a maximum of 1% manganese. This alloy is used extensively as it has high tensile strength with good low-temperature properties.

Mr. BOWDLER: What about explosions? I know that it is possible for liquid oxygen and kerosene to be detonated if large volumes are accidentally mixed together and the conditions arise where detonation can occur. I can think of conditions in which a large amount of detonation could take place. What about detonation problems?

Mr. BREEN: Yes, there is, of course, a great hazard, and it is for this reason that one finds these test stands in the most out-of-the-way places. The whole test installation is, first of all, designed as though it was inevitable that a serious accident was going to take place. Therefore, everything is spaced out with a view to the explosion being restricted, in its damage, to the stand. Vital high pressure storage areas—for instance, for gaseous nitrogen—might be protected against falling debris and the like. That is the first step.

Perhaps the worst hazard that one has to think of is not so much the huge volumes of propellents becoming mixed together, which is extremely unlikely, because for that to happen there would have to be a rupture of both tanks, and that would be a really major incident and if you got to that stage you could probably write off the stand. The worst problem that one has to deal with is the rather smaller spillage that might come from fractured lines before cut-off could be effected. In that connection, as you probably know, if you mix liquid oxygen and kerosene you are liable to form explosive gels, and in such case the water film on the flame deflector assumes a second role, which is to act as a disposal system. During the time in which the tanks are charged—not necessarily when the engine is firing—an additional volume of water is played on the deflector, and the idea is that fuel or oxygen falling there will be carried away rapidly.

I do not think there is any complete safeguard. All sorts of forms of protection are used, such as torpedo nets and large screens and remote control apparatus so that there are no personnel in the vicinity. We protect the personnel by keeping them right out of the area. The fact that hazards exist is recognised, and I think that is the greatest safeguard.

Mr. PEARSON: Are there any major reasons why the rig cannot be turned the other way and the blast taken upwards?

Mr. FORSTER: That is a rather novel approach. I do not think that has been tried. I cannot give you an answer to that question.

A MEMBER: I think I can probably answer that question. Mr. Pearson says: if the nozzle goes upwards, why do we not fire downwards and thrust into the earth?

Mr. PEARSON: No. I asked why one should not turn the whole rig upside down and fire the flame upwards.

The MEMBER: If you do that and do not get a firing, you have a beautiful explosive gel and the combustion chamber will be full of an explosive mixture, which is extremely dangerous. If the engine is put the other way it is easy to fire, and, also, should you get ignition not taking place the fuel will fall out of the chamber and be washed away.

The Chairman: It is also argued that normally the rocket engine is thrusting and is being accelerated in the opposite direction to the jet, and therefore it is natural to fire and test it that way up. At least, the acceleration is in the right direction.

Mr. LENNOX-NAPIER: It might be added that for much the same reason these large engines are generally not fired horizontally. They do not have any range in the horizontal direction, and any angle nearer to horizontal than 45° tends to become dangerous with regard to things in the combustion chamber.

Mr. STOCKTON: Would any more difficulties than usual occur with a rocket engine using nitric acid and aniline, owing to the acid properties of the components in the flame?

Mr. BREEN: If you were using propellents which have a corrosive action, I think it would be fair to say that it is no more of a hazard than when using liquid oxygen, which brings the hazard of embrittlement fracture. In other words, the main danger is from a spillage. Spillage of liquid oxygen causes great thermal shock and therefore mechanical failure of the structural members or the flame deflector itself. The spillage of an acid has a corrosive action. Provided you took immediate remedial action and flushed out with alkaline solution, I can see no real stumbling block there. I think the major hazard is a liquified propellent at an extremely low temperature.

Mr. C. R. CROSSE, M.I.P. (Secretary, Institution of Plant Engineers): What is the average thickness of the film of water over the deflector?

Mr. FORSTER: The jets run to about ½ in. diameter, and the spray is flattened out. The water layer is probably about ¼ in. or less in thickness. As I said, the holes are spaced in the impingement area at about 3 in. centres in equilateral triangles. There is definite evidence that one can burn through a 1-in. plate in about 5 sec. if there is a bare spot without any water. On the other hand, with proper distribution of the water the plate temperature remains somewhere under the boiling point of water.

A MEMBER: In view of the embrittlement problem, has there been any trouble in the way of water causing stressing problems in relation to the liquid oxygen hydraulic system?

Mr. BREEN: In the main liquid oxygen system we certainly have to take into account hydraulic effects, but there is no particular need to consider embrittlement in that relationship because we make the whole thing of austenitic steel, which does not suffer from this defect. There is a considerable surge load when you close the main valve of the engine. That valve has to be capable of being shut just as quickly as you can shut a valve. It is done at a very high speed indeed, and you stop a very high flow in a very short space of time and considerable loads have to be catered for. These loads are additional to the contraction load, and that in itself causes stressing of the pipe. If you do not permit it to take place—that is, if you restrict the contraction—then there is a resulting stress in the pipe. It is not always possible to allow contraction to take place, and sometimes we have to design deliberately for increased stressing due to contraction on cooling.

There is an additional fact to be considered more in relation to pressure vessel design rather than pipework in that in

computing the thickness of the pressure vessel one has to make allowance for thermal shock or stress during the initial filling or cooling down period.

A MEMBER: You mentioned the possibility of a leakage past the valves. Have plastic materials been used as seals in those valves?

Mr. FORSTER: Yes, very extensitvely. Various materials have been used, including Hostaflon and Fluon.

A MEMBER: I imagine that test rigs will vary somewhat from the final rocket motor. Do you find that any modifications are required to your test figures when you finally get the rocket in flight?

Mr. BREEN: I do not think we are really qualified to answer that question. That is exactly the sort of question that I was scared of getting tonight. The point that I would put to you is that we are rocket facility engineers as distinct from rocket engineers, and I hesitate to tread in the field of the rocket engineer, especially in the presence of Dr. Shepherd and many other experts here tonight. However, in spite of the fact that I hesitate to tread in that field, if I thought I knew the answer I would give it, but I do not.

Mr. IAN MACLEAN (Chairman, London Branch, Institution of Plant Engineers): The emphasis in connection with this rocket test work seems to be largely on hazard. Do the Factory Inspectorate take any interest in this, or have they not yet caught up with you, I wonder? Also, I suppose that in the design of a new rocket the hope is that it will go off correctly, but do you really expect that at the first firing you will get things to go without any trouble, or is that something which very rarely happens?

Mr. FORSTER: As far as possible all precautions have been taken to conform to the Factory Inspectorate standards. The vessels have manholes conforming to the standards. Everything, particularly in the workshop areas and so on, is in accordance with the requirements of the Factories Acts. As to the facility itself, we have a state of affairs where no one would ever be on the job when it was actually working, because there are very low safety factors in relation to the rockets and the engines. However, I do not think a factory inspector would wish to be there, or would wish anybody else to be there, when the engine was in operation. Therefore, it is impossible to meet all the requirements actually on the stands themselves, but throughout the site they are met as far as possible.

The second question was whether the rocket works first time. With the Black Knight in Australia we have had 100% successful firings—there have been no failures—and that is something that the Americans have never achieved. We do not know how many failures the Russians have had.

Mr. STOCKTON: Are the Americans likely to have a great deal of trouble when they test the Saturn rocket, which they have, I think, completed now? I do not know whether they have yet tested it in a test bed. I should not think that the ordinary rocket test beds would be able to deal with such a capacity as that rocket has. I do not think the Americans have stands of the necessary size, let alone the strength.

Mr. BREEN: As to size, I can only quote from the popular press, by which I mean popular among rocket engineers—*Jet Age*, *Aviation Weekly*, and so on. An article which I saw recently had a very nice artist's impression of the latest North American Aviation stand designed for testing engines with 1½ million lb. thrust. I have not seen any actual photographs.

A MEMBER: Will Mr. Forster say something about the ignition process and its hazards and also about the types of flowmeters used?

Mr. FORSTER: Ignition is a function of the engine itself, and even if we were concerned with that, I should not be permitted to say anything about it here.

Flowmeters are extensively used. They are generally of the spinning vane type. They are very fragile and very subject to shock, very much like the mechanism of a watch, and great precautions have to be taken to ensure that one is getting liquid through, because if you get a sudden burst of gas they can be accelerated to high speeds and easily wrecked. However, under proper conditions they are very reliable and accurate.

The CHAIRMAN: I think we have perhaps subjected our two speakers to a sufficient bombardment of questions, and so I call upon Mr. Mitchell, a Fellow of the Institution of Mechanical Engineers and Vice-Chairman of the London Branch of the Institution of Plant Engineers, to propose a vote of thanks to the authors of the paper.

Mr. G. L. MITCHELL: I am sure you will all agree that we have listened to a paper on a very fascinating subject. I am only a plant engineer and many of those present are better equipped to understand the paper than I am. A layman like myself might think, on seeing the pictures on the screen, that he was in an operating theatre and that a human body was being dealt with in a major operation. The authors and their colleagues can carry out their operations on sites similar to those we have seen on the screen. I know a little about such sites, being a civil engineer as well, and it astounds me that they can achieve the necessary accuracy for their experiments.

We thank the members of The British Interplanetary Society who have attended the meeting and, I assume, have asked most of the intricate questions. I am sure that very few plant engineers could have asked such questions.

We also thank the authors—and their company for allowing them to come here and give us such a very absorbing paper—and we thank Dr. Shepherd for presiding over the meeting.

The votes of thanks were accorded with acclamation, and the meeting then terminated.

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OPTIMUM TRAJECTORY OF *n*-STAGE MISSILES*

By HARRY W. HARCROW†, A.B.A., B.S.

ABSTRACT

A method is presented for obtaining the maximum range with minimum propellent expenditure by a series representation which precludes the use of calculus of variations. Optimum staging techniques, Lagrangian equations of motion, and the equations of powered flight are used for the development of this method.

I. INTRODUCTION

THE flight path or trajectory of an *n*-stage missile is developed in three phases. These include burning or powered stages, coasting between the powered stages, and re-entry phase. The re-entry phase is an extensive subject within itself and will be covered at a later date in a subsequent paper. Several authors, notably Leitmann[1], Ross[2], Bryson and Ross[3] and Wheelon[4] have approached the subject of the optimum trajectory. It is the purpose of this paper to develop considerations for optimum trajectories of *n*-stage missiles. This will be accomplished by optimizing the firing angle, α, and coasting or free flight periods.

It is well known that a coasting or free flight period is desirous between powered stages for maximum range at a minimum propellent consumption. By optimizing these coasting periods and allowing the particular powered stage to fire only at its optimum firing angle we eventually obtain the optimum trajectory. It is advantageous to use digital computers for this optimization.

Several approximations are made to simplify our problem:

(1) The first stage is the only stage that has aerodynamic forces.

(2) Earth is considered spherical in shape.

(3) Centre of gravity is assumed along the centreline of the missile.

(4) No effects due to yaw or altitude changes occur.

Considering that the missile follows a two-dimensional path defined in rectangular co-ordinates, the kinetic and potential energies are expressed:

$$\text{Kinetic energy} = \tfrac{1}{2}m(\dot{x}^2 + \dot{y}^2) \quad .. \quad (1)$$

$$\text{Potential energy} = m\,g\,y \quad .. \quad .. \quad (2)$$

Transforming these equations into cylindrical co-ordinates:

$$x = r\cos\theta \quad y = r\sin\theta$$

$$\text{Kinetic energy} = \tfrac{1}{2}m\,(\dot{r}^2 + r^2\,\dot{\theta}^2) \quad .. \quad (3)$$

$$\text{Potential energy} = m\,g\,r\sin\theta \quad .. \quad (4)$$

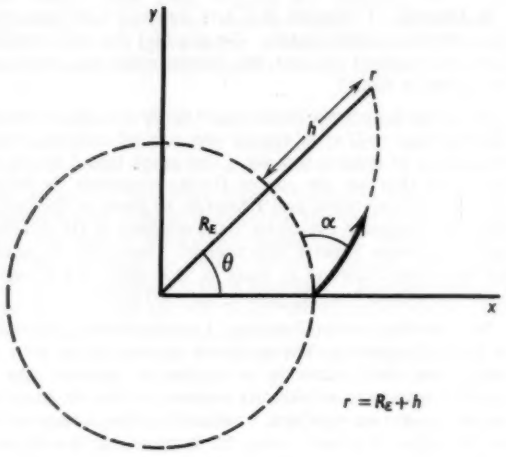

FIG. 1

and the Lagrangian is then expressed as

$$L = \tfrac{1}{2}m\,\dot{r}^2 + \tfrac{1}{2}m\,r^2\,\dot{\theta}^2 - m\,g\,r\sin\theta \quad .. \quad (5)$$

The equations of motion may be obtained using Lagragian equations of the form

$$\frac{\partial L}{\partial r} - \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{r}}\right) = 0; \qquad \frac{\partial L}{\partial \theta} - \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\theta}}\right) = 0$$

Substituting Equation (5), we obtain

$$m\,r\,\dot{\theta}^2 - m\,g\sin\theta - m\,\ddot{r} = 0$$

or

$$r\,\dot{\theta}^2 - g\sin\theta - \ddot{r} = 0 \quad .. \quad .. \quad (6)$$

and

$$-\,m\,g\,r\cos\theta - m\,r^2\,\ddot{\theta} = 0$$

or

$$g\cos\theta + r\ddot{\theta} = 0 \quad .. \quad .. \quad .. \quad (7)$$

The equation of motion of the missile is now given by setting Equation (6) equal to (7) to obtain

$$\ddot{} + g\sin\theta - r\,\dot{\theta}^2 + r\,\ddot{\theta} + g\cos\theta = 0 \quad (8)$$

* Manuscript received 3 October, 1960.

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Note that the equation of motion of the missile is independent of mass.

To obtain the optimum trajectory we will compute optimum range for a single stage, then consider n stages, with subsequent checks and necessary variations of the initial conditions.

II. POWERED SINGLE STAGE

The propulsive force of a particular missile may be determined from consideration of momentum.

$$M_b = M_0 - \mu \quad .. \quad .. \quad .. \quad (9)$$

Therefore

$$MV = (M_0 - \mu)\, V \quad .. \quad .. \quad (10)$$

After mass $d\mu$ is ejected,

momentum of rocket $= (M_0 - \mu - d\mu)\,(V + dV)$ (11)

and the momentum equal in magnitude but opposite in direction to that of the ejected gas during a particular interval is $d\mu\,(V - V_g)$ where V_g = gas velocity.

Since the linear momentum of the rocket plus the momentum of the ejected gas is constant, then

$$(M_0 - \mu)\, V = (M_0 - \mu - d\mu)\,(V + dV) + d\mu\,(V - V_g) \quad .. \quad .. \quad (12)$$

Ignoring second order infinitesimals we obtain

$$M\,dV \cong (M_0 - \mu)\,dV \cong V_g\,d\mu \quad .. \quad (13)$$

or

$$M\frac{dV}{dt} = V_g\frac{d\mu}{dt}$$

which states that at any instant the acceleration multiplied by the total mass of the system at that instant is equal to the gas velocity multiplied by the rate of the mass flow. This represents the thermal thrust or propelling force.

$$F_T = V_g\frac{d\mu}{dt} = M\frac{dV}{dt}$$

We now assume that the aerodynamic and gravitational forces have been resolved to act along the trajectory and in the direction of motion. Equation (13) becomes

$$M\frac{dV}{dt} = F_T + F_g + F_a$$

or

$$\frac{dV}{dt} = \left(V_g\frac{d\mu}{dt} + F_g + F_a\right)\frac{1}{M_0 - \mu}$$

and

$$\frac{dV}{dt} = a_t + \frac{F_g + F_a}{M_0 - \mu} \quad .. \quad .. \quad (14)$$

where

$$a_t = V_g\frac{1}{M_0 - \mu}\frac{d\mu}{dt}$$

and is the acceleration produced by the jets alone. The acceleration of the missile is now seen to be equivalent to the acceleration produced by the jets plus the external forces acting upon the missile divided by the mass at any particular time during burning.

If we assume that the pressure differential is appreciable, we must include this effect. Therefore,

$$a_t = \frac{(P_E - P_A)\,A_E}{(M_0 - \mu)} + \frac{V_g}{(M_0 - \mu)}\frac{d\mu}{dt} \quad (15)$$

This applies to a simplified propulsion device, considering the missile as a closed duct open at one end. If we consider a constant exit pressure (assuming the propellent is burnt at a constant rate), and exit area, the acceleration of the missile at time t may be expressed as:

$$a_t = \sum_{i=1}^{t}\left[\frac{(P_E - P_{A_i})A_E}{(M_0 - \mu_i)} + \frac{V_g\,\dot{m}_i}{(M_0 - \mu_i)}\right]\tau \quad (16)$$

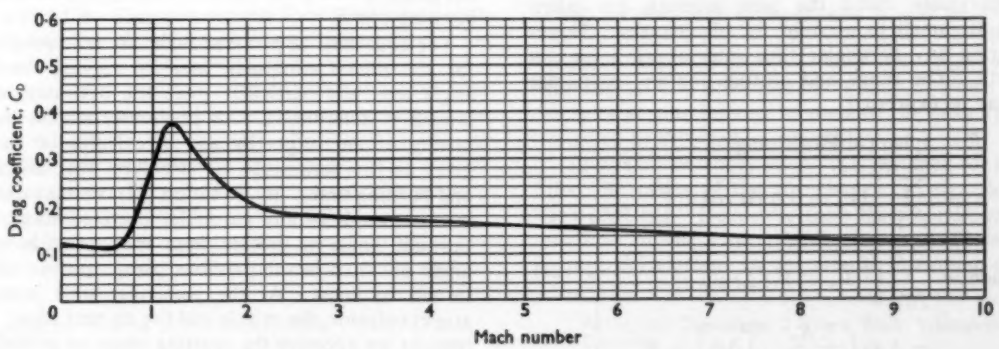
Considering a ballistic type of missile with no lifting forces, the aerodynamic forces comprise only the drag force. This may be expressed, in simplified terms, as:

$$F_a = 0{\cdot}5\,\rho\,C_D\,S\,V^2 \quad .. \quad .. \quad (17)$$

and the gravitational force is given by:

$$F_g = (M_0 - \mu)\,g\sin\alpha \quad .. \quad .. \quad (18)$$

Substituting Equations (17) and (18) into Equation



(14) we obtain the acceleration of the missile at any time during burning as:

$$\frac{dV}{dt} = \frac{(P_E - P_A)\,A_E}{(M_0 - \mu)} + \frac{V_g\,d\mu}{(M_0 - \mu)dt} + \\ + \frac{0{\cdot}5\rho\,C_D\,S\,V^2}{M_0 - \mu} + g\sin\alpha \quad .. \quad (19)$$

or

$$V = \sum_{i=1}^{t}\left[\frac{(P_E - P_{Ai})A_E}{(M_0 - \mu_i)} + \frac{V_g\,\dot{m}_i}{(M_0 - \mu_i)} + \right. \\ \left. + \frac{0{\cdot}5\rho_i c_{Di}\,S\,V_{i-1}^2}{(M_0 - \mu_i)} + g_0\left(\frac{R_E}{R_E + h_i}\right)\sin\alpha_i\right]\Delta t \quad (20)$$

It should be noted that this equation assumes that the intervals of time are significantly small as to account for all variable changes.

The velocity expressed above is the tangential velocity of the missile achieved during powered flight.

Recall in our original assumptions that aerodynamic forces are ignored beyond the primary powered stage. This assumption produces only a negligible error since the atmospheric density is sufficiently small in regions above the atmosphere and this paper assumes no re-entry forces. Although the ejected mass of the missile is in fact a function of time we may take the ejected mass for any particular interval of time as a mean ejected mass and the resulting error would be negligible.

III. VEHICLE WITH $n + 1$ STAGES

Considering this and also a constant pressure differential, the equation for tangential velocity of $n + 1$ stages is:

$$V = \sum_{i=1}^{t}\left[\frac{P_D\,A_E}{(M_0 - \bar{\mu}_i)} + \frac{V_g\,\dot{m}_i}{(M_0 - \bar{\mu}_i)} + \right. \\ \left. + g_0\left(\frac{R_E}{R_E + h_i}\right)^2\sin\alpha_i\right]\Delta t + v_0 \quad .. \quad (20a)$$

where

$P_D = P_E - P_A$ = constant pressure differential above the atmosphere.

As previously stated the time intervals are taken significantly small to account for all changes. Therefore during any particular time interval we assume a flat Earth. The range and altitude for any particular stage may be expressed:

$$\left.\begin{aligned} R &= \text{spherical Earth range} \\ &= \sum_{i=1}^{t}\left[(V_0 + V_i)\,\Delta t\cos\alpha_i\right] \\ \text{Altitude} &= \sum_{i=1}^{t}\left[(V_0 + V_i)\,\Delta t\sin\alpha_i - \right. \\ &\quad \left. - \tfrac{1}{2}\,g_0\left(\frac{R_E}{R_E + h_i}\right)^2\Delta t^2\right] + h_0 \end{aligned}\right\} \quad (21)$$

where V_0 and h_0 are the initial values of velocity and altitude respectively.

The angle of launch, α, is defined by the expression

$$\alpha = \text{arc cos}\,(R/vt)$$

or

$$\alpha_t = \text{arc cos}\,(R_t/v_t\,\Delta t) \quad .. \quad .. \quad (22)$$

where v_t and R_t are the velocity and range of any particular time interval. Then α_t is the launch angle of a particular time interval.

The problem, therefore, has resolved itself into two parts, that of powered and coasting periods.

For the coasting phase Equation (20a) becomes

$$V = \sum_{i=1}^{t} g_0\left(\frac{R_E}{R_E + h_i}\right)^2\Delta t\sin\alpha_i + V_0 \quad .. \quad (20b)$$

taking the velocity of the preceding stage as its initial velocity.

We have, therefore, defined a series of equations to determine the trajectory of a missile through either its coasting or powered phases. But, as yet, we have not solved for the trajectory for optimum range.

Several authors, notably Schurmann[5], Subotowicz[6] and Hall and Zambelli[7], have discussed the optimization of multistage missiles by Lagrangian multipliers with reference to propellent economy and structure parameters. But optimization of the trajectories of n-stage missiles must consider minimum propellent for maximum range and, therefore, flight parameters have to be considered.

Using Equation (20b) in conjunction with Equation (21), we may determine the maximum range of the missile during its coasting or free flight period for a given initial velocity and altitude. This is accomplished by allowing the launch angle, α, to vary over the programme till an optimum is obtained. An electronic computer was not available to the author at completion of this paper. But if the results obtained were plotted for initial velocity *vs.* range for specific launch angles, the graph would yield optimum angles of launch for any coasting phase.

The equations of powered flight are now programmed for the digital computer, and by varying the launch angle over any particular stage the optimum angle of launch is determined. As previously stated, the optimizing of the stages by use of calculus of variations gives us the parameters of structure, fuel distribution, and burning time. By Equation (22), we may obtain the burnout angle of any particular powered stage. If the burnout angle is greater than the optimum coasting angle obtained in the previous paragraph, we allow the missile to coast. At the particular time when these angles coincide, the missile will fire its next stage. In this manner we optimize the coasting phase or period of free flight.

It should be noted that after any powered or coasting period the optimum range is verified by allowing α to vary slightly. In this manner we obtain the truly optimum angle.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude for the assistance and advice freely given by Lloyd Beam and Richard Robinson. Without their help this paper would not have been possible.

LIST OF SYMBOLS

a	acceleration produced by jets alone.
g	$= g_0 (R_E/R_E + h)^2$.
g_0	acceleration at Earth's surface, 32·2 ft. sec.$^{-2}$
h	altitude from Earth's surface.
m	mass.
$\dot{m}$	mass flow.
n	number of stages in missile.
r	cylindrical co-ordinate ($= R_E + h$).
t	time.
Δt	time interval.
v	velocity.
x, y	rectangular co-ordinates.
A_E	exit area.
C_D	drag coefficient.
F	total net thrust.
F_a	aerodynamic force.
F_g	gravitational force.
F_T	thrust developed.
L	Lagrangian.
M	mass of rocket.
M_b	mass of rocket after a burning period.
P_A	local atmospheric pressure.
P_D	$= P_E - P_A$.
P_E	exit pressure.
R	spherical Earth range.
R_E	radius of Earth.
S	surface area.
V	velocity.
V_E	exit velocity of ejected mass.
V_g	gas velocity.
α	angle between tangent to the flight path and a line perpendicular to the gravitational field.
θ	angle of rotation reference centre of Earth.
$\Delta\theta$	change in angle of rotation.
μ	ejected mass.
$\bar{\mu}$	mean ejected mass during a specific interval of time.
ρ	atmospheric density.
τ	non-dimensional time interval.

Subscripts

o	initial.
i	condition at stage i.
t	condition at time t.

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MINIMUM ENERGY ENTRY INTO PLANETARY SATELLITE ORBITS*

By S. W. GREENWOOD,† M.Eng., A.M.I.Mech.E., A.F.R.Ae.S., Member of Council

ABSTRACT

Entry into the orbit of a planet may be assisted by entry into a suitable satellite orbit around the planet. The circular satellite orbits for minimum energy are determined for the planets of the Solar System, assuming transfer along a minimum energy semi-ellipse from Earth. The effect is of practical interest for flights to Mercury and Mars.

INTUITIVELY, the author has long supposed that it is easier to enter the orbit of a planet distant from the planet than to approach close to the planet and go into orbit around it. One instinctively feels that coping with the fall into the planet's gravitational field will call for a higher velocity requirement from the vehicle.

However, entry into the orbit of another planet does necessitate that the vehicle experiences a change in velocity relative to the transfer orbit, and it will be shown that judicious selection of a satellite orbit around the target planet permits making use of the planet's field to assist entry into the planet's orbit.

It must be admitted at once that the effect turns out to be of largely academic interest except in the case of the smaller planets. Moreover, it is an effect that appears to have escaped attention hitherto, as most studies have been based on entry into satellite orbits close to planetary surfaces, and it will be shown that for such cases the velocity requirement is appreciably reduced only for Mercury, and only slightly reduced for Mars. For other planets (excluding Pluto, which is only of remote interest at present) the velocity requirement is, as expected, increased.

In this introductory study, it is assumed for simplicity that the orbits of the planets are circular, concentric, and coplanar. Departure from these conditions is only marked in the case of Mercury and Pluto. More precise calculations are required to determine the actual

* Manuscript received 22 November, 1960.

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minimum energy satellite orbits, but this study should serve to indicate orders of magnitude and suggest the most profitable areas for future investigation.

It is assumed that conventional rocket systems are employed, so that the minimum energy transfer may be accomplished along a cotangential semi-ellipse. It is appreciated that this is probably not a practical technique for flights to distant planets.

For orbits within the Earth's orbit:

$$V_1 = \sqrt{V_E^2 + (V_P - V_O)_2} - V_E/\sqrt{2}$$
$$V_2 = V_P - V_O$$

For orbits outside the Earth's orbit:

$$V_1 = \sqrt{V_E^2 + (V_O - V_A)^2} - V_E/\sqrt{2}$$
$$V_2 = V_O - V_A$$

where:

V_1 = velocity requirement for entry into circular orbit around destination planet at distance where planet's escape velocity is V_E (and hence circular orbital velocity is $V_E/\sqrt{2}$),

V_2 = velocity requirement for entry into orbit of destination planet, distant from planet,

V_P = velocity at perihelion of transfer semi-ellipse,

V_A = velocity at aphelion of transfer semi-ellipse,

V_O = velocity of destination planet in orbit.

For simplicity, put:

$$x = \begin{cases} V_P - V_O \text{ (for orbits within the Earth's orbit),} \\ \text{or} \\ V_O - V_A \text{ (for orbits outside the Earth's orbit)} \end{cases}$$
$$y = V_E$$
$$z = V_2 - V_1$$

Then $$z = x - \sqrt{y^2 + x^2} + y/\sqrt{2}$$

or $$z/x = 1 - \sqrt{(y/x)^2 + 1} + (y/x)/\sqrt{2}$$

The function z/x is plotted against y/x in Fig. 1.

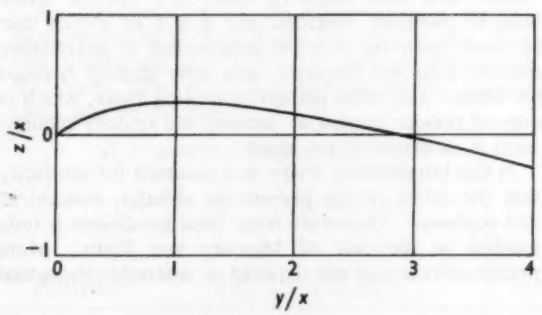

FIG. 1. Plot of velocity saving (z/x) against strength of planet's gravitational field in satellite orbit selected, expressed in dimensionless form (y/x).

The quantity z/x represents the proportion of the velocity change required for entry into the planet's orbit that may be saved by using the planet's gravitational field, in entering a circular satellite orbit around the planet. y/x represents the equivalent strength of the planet's gravitational field at the distance chosen for the circular orbit relative to the velocity change required for entry into the planet's orbit distant from the planet.

Savings may therefore be effected in regions where z/x is positive, and this is the case for values of y/x from 0 to $2\sqrt{2}$ (or 2·83). For all higher values of y/x, z/x is negative, and no saving may be effected. z/x is a maximum at $y/x = 1$, and this represents the condition of the greatest saving, and therefore of minimum energy requirement. The greatest possible proportional saving is $(1 - 1/\sqrt{2})$, or about 30%, of the destination velocity change.

For all the planets except Mercury, y at the planet's surface is greater than x. It is thus possible to find an altitude at which $y = x$ and so permits advantage to be taken of the maximum saving. In the case of Mercury, however, y at the surface is less than x, and we are therefore constrained to the region to the left of the maximum in Fig. 1. Here we need y/x to be as high as possible to get the best saving, and this is given by an orbit as close to the planet's surface as practicable, and the saving comes out at about 22% of the destination velocity change.

If R is the radius of the minimum energy satellite orbit, and R_0 the radius of the planet, we have:

For Mercury: $R/R_0 = 1$.

For other planets: $\sqrt{R/R_0} = y_0/x$

where y_0 is the escape velocity at the surface, and $x = y$ for the minimum energy condition.

Data of interest are listed in Table I. The usual note of caustion must again be sounded on the unreliability of some planetary data. Pluto is particularly suspect, but this does not affect us much.

It will be seen that velocity savings of about 1 mile/sec. are generally possible. Ignoring Pluto, it will be seen, however, that the satellite orbits involved are at such large relative distances from planetary surfaces in most cases as to be of little more than academic interest. The exceptions are Mercury and Mars.

The velocity savings, expressed in terms of V_3, the velocity required to depart from the Earth's surface and to enter the planet's orbit, are also shown in Table I. These savings come out at between 5 and 10%, a fairly useful contribution to the missions. Mercury shows up best on this count, with Mars near the lower end of the range.

The savings in the case of Mercury may be more clearly seen in Fig. 2. This is a plot of the velocity requirement for entry into a circular orbit around the planet at different multiples of the planet's radius. The saving is greatest at the surface and progressively less as one proceeds further from the surface.

TABLE I

	Mercury	Venus	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
y at surface, miles/sec. ..	2·67	6·46	3·16	37·9	22·7	13·90	15·91	3·28
x, miles/sec.	6·00	1·60	1·66	3·52	3·36	2·93	2·54	2·34
y/x for $(z/x)_{max}$	0·445	1	1	1	1	1	1	1
$(z/x)_{max}$	0·2215	0·293	0·293	0·293	0·293	0·293	0·293	0·293
z_{max} miles/sec.	1·33	0·47	0·49	1·03	0·99	0·86	0·74	0·69
V_3 miles/sec.	14·34	8·69	8·78	12·29	12·72	12·75	12·55	12·40
z_{max}/V_3, %	9·3	5·4	5·6	8·4	7·8	6·7	5·9	5·6
R/R_0	1	16·3	3·63	116·5	45·7	22·6	39·3	1·96

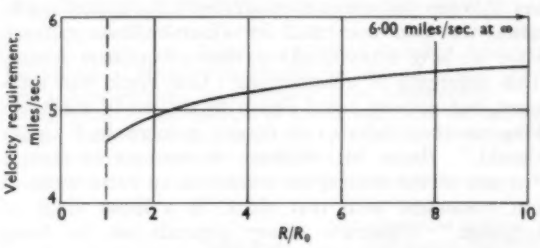

FIG. 2. Dependence of velocity requirement at destination on radius of satellite orbit entered for Mercury.

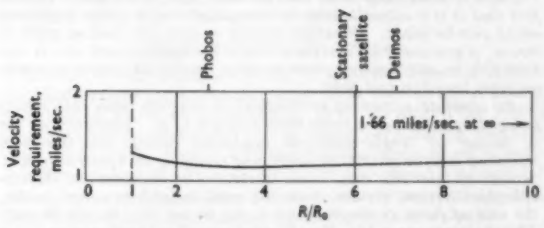

FIG. 3. Dependence of velocity requirement at destination on radius of satellite orbit entered for Mars.

For Mars, the picture is presented in Fig. 3. Here, the greatest saving occurs at 3·63 planetary radii. The curve is fairly flat in this region, and useful savings are possible in the zone between the planet's two natural moons. The relative position of a "stationary" satellite rotating at the same angular velocity as the planet is indicated.

Before concluding, it is of interest to note that a similar approach may be made to the problem of establishing satellites around our own Moon. The ratio of the Moon's gravitational field strength to the velocity change at apogee is, however, large, and the theoretical saving in velocity requirement is negligible, in addition to the associated orbit being so distant from the Moon as to be impracticable, and to render the simplifying assumptions invalid.

The above study arose out of the author's puzzlement when he discovered that it is easier to enter orbits around Mercury and Mars than it is to enter the orbits of these planets. He hopes that this will prevent further puzzlement.

CORRESPONDENCE

(In these letters to the Editor, some passages have necessarily been omitted)

The Journal

SIR,

It is with pleasure that I read today in the *Journal* for August the general widening of ambition for the Society by the executives. As an electrical power engineer I find that most of my time is occupied in keeping abreast of the many advances day to day in that field. I find also that in the widening and more practical aspects of space flight, travel or what you will, all science and engineering becomes more and more intelligible as we are all drawn nearer by the demand for sources of power, metering, communications and so on, as the dream which we all know is inevitable becomes closer and closer in our time.

At the time of the increase in the subscription rates I was critical, in the light of past experiences. May I now express my approval of the great improvements in publications and publicity of the Society, and of course its standards, undoubtedly helped by the extra revenue.

Thank you again,

Yours faithfully,

J. NUNNELEY.

Lindley House, Whitefield Road,
New Milton, Hampshire.

22 *September*, 1960.

Thrust Units

SIR,

This is to plead that we should in future discuss rocket thrust in terms of *tons* instead of *hundreds of thousand* (or *millions*) *of pounds*, as at present.

A space vehicle quoted as giving 700 tons of thrust at take-off at once conveys the scale in a way analogous to sea-going terminology; it is a "700-tonner." One million four hundred thousand pounds just conveys a lot of noughts. We are getting too big for this sort of thing!

Yours faithfully,

Hoo Mill, M. W. HARTFORD.
Watlingford, Oxfordshire.
15 *November*, 1960.

There is something to be said for Mr. Hartford's point, but we feel that it is a minor matter in comparison with other criticisms which can be made. Whether pounds or tons are used as units of thrust, a gravitational system of units is employed and this is undesirable in astronautics, since we have to consider travel in a non-uniform gravitational field.

An absolute system is preferable; in English units this means using the poundal or a convenient multiple of it. However, we are in favour of Anglo-American engineers falling into line with scientists and the rest of the world, and changing to a metric system. Sooner or later this must come about. The Rationalized Metre-Kilogram-Second system seems the most suitable to adopt; in this, the unit of force is the Newton (1 kg.m.sec.$^{-2}$ = 0·2249 lb.wt.). *This does not meet Mr. Hartford's point about rocket thrusts, as it is even smaller than the present unit, but it would be possible to express thrust in terms of* kilonewtons. *The vehicle he quotes would have a thrust of* 7000kN.

Relativity and Space Travel

SIR,

Mr. Herman[1] is not playing fair. I said quite clearly[2]: "For simplicity, let us suppose that R and R' are synchronized after M has begun its journey, so that no question arises about the effect on R' of M's initial acceleration". Mr. Herman now invokes a discrepancy of v^2T/c^2 between R and R' which is produced during that acceleration. But that is wiped out by the subsequent synchronization, which I stipulated precisely in order to keep this red herring out of the way. My question remains, and I still await Mr. Herman's reply.

My stipulation is certainly legitimate. If Mr. Herman challenges it, then he must hold that when a traveller to a distant star comes back after 50 years of Earth-time, the question whether he will have aged by 6 months or 50 years will depend on whether Jodrell Bank communicated with the star just before he started his engine or just after he switched it off. I know how credulous believers in asymmetrical ageing can be, but I don't think they go that far. I am therefore entitled to insist on my statement of the problem.

But in fact I don't need to insist on it. I can accept Mr. Herman's, and then the question I put to him is this. Suppose R and R' test their synchronization just before M starts his engine and again between his stopping it and arriving at the star. Then, on Mr. Herman's view, if M is the moving body the tests will agree, and if R is the moving body they will not. What in fact will be observed? I leave it to Mr. Herman to choose between my earlier question and this.

Mr. Herman's remarks about clock readings for distant events are misleading. On Einstein's theory, in a given co-ordinate system the time of *any* event has a unique value, given by *any* clock stationary in the system which has been synchronized with the standard clock at the origin. The establishment of this was the essential first step in the theory, and, having secured it, Einstein concluded[3]: "It is essential to have time defined by means of stationary clocks in the stationary system, and the time now defined being appropriate to the stationary system we call it 'the time of the stationary system'". Not, be it noted, the time by the one clock at the event in question, but "the time of the *stationary system*". Again, Einstein and Infeld,[4] explaining this in detail, say: "When discussing measurements in classical mechanics, we used one clock for all co-ordinate systems. Here we have many clocks in each co-ordinate system. This difference is unimportant. One clock was sufficient, but nobody could object to the use of many, so long as they behave as decent synchronized clocks should." Hence Mr. Herman is incorrect in saying: "to talk of the reading on a clock at an event which is not coincident with that clock, is a loose usage of language." Einstein's theory depends on its being precise.

Again, Mr. Herman misses the point in his last paragraph when he says: "the field always appears and disappears in synchronism with the operation of the motor controls." It doesn't: it appears and disappears in synchronism with the operation of Mr. Herman's mind in changing from one co-ordinate system to another. That is the difference between this fictitious gravitational field and an actual one. When the apple falls to the ground you can express the fact by assuming a gravitational force of attraction or by choosing a co-ordinate system in which the apple moves freely along a geodesic; but in either case the apple falls to the ground. In the case of M and R, however, there are no undeniable clock changes behind the descriptions. R and R' go out of synchronization if the field exists but if you change your coordinate system so that the field vanishes, there is no phenomenon left to describe. Hence the supposed gravitational field is not needed to explain something that is observed to happen, but only (and ineffectively) to save a false theory from refutation.

HERBERT DINGLE.

104 Downs Court Road,
Purley, Surrey.
15 *March*, 1961.

REFERENCES

1. R. Herman, *J.B.I.S.*, 1961–62, **18**, 40.
2. H. Dingle, *ibid.*, 1959–60, **17**, 98.
3. A. Einstein, *Ann. Phys.*, 1905, **17**, 891; translated in "The Principle of Relativity," p. 40. **1923**: London (Methuen).
4. A. Einstein and L. Infeld, "The Evolution of Physics," p. 191, **1938**: Cambridge (Cambridge University Press).

NEWS AND ANNOUNCEMENTS

B.I.S. NEWS

Sixteenth Annual General Meeting

The date chosen for this year's Annual General Meeting is Friday, **15 September, 1961**. Members are reminded that notice of nomination for election to the Council is required at least 12 weeks before the date fixed for the meeting. The nomination forms, which are obtainable from the Secretary, must therefore be completed and returned by **23 June, 1961**. However, it would be appreciated if nominations could be made before this date, to facilitate the preparation of the necessary ballot forms, which must be printed, distributed and returned within the 12-week period, and this includes the summer holiday peak months.

Compounded Subscription Changes

At its meeting on 25 March, 1961, Council resolved that the Compounded Subscription Scale be amended as from that date by requiring the payment of £26 for Fellowship, Associate Fellowship or Senior Membership for ages of 51 and over, and a corresponding payment of £23 for Membership.

This involves the deletion of the former rates for the age limits 51-55, 55-60 and over 60, so that the compounded subscription rates are now as follows:

	Members		Fellows, Associate Fellows and Senior Members	
Age	£	$	£	$
20–25	41	115	50	140
26–30	37	105	45	126
31–35	34	95	40	112
36–40	31	87	36	100
41–45	28	79	33	92
46–50	26	73	30	84
over 50	23	64	26	73

It is hoped that as many members as possible will take advantage of this method of payment. It benefits the Society, which has the immediate use of a lump sum; these payments are invested and credited to a special account in readiness fr future use in purchasing headquarters for the Society or for similar purposes.

The member benefits by paying a much smaller sum than would be required over the years in separate annual fees. This is particularly advantageous if it should become necessary to increase the annual subscription.

Another convenient method of payment which has proved popular (over 400 members already employ it) is by use of a Banker's Standing Order; forms for this are obtainable from the Secretary.

Formation of Australian Groups

A further step has been taken in the direction of establishing the proposed Australian Branches previously mentioned in the *Journal* (Dec., 1960, **17**, 463). Three provisional groups have been set up and are organizing meetings and other activities. Australian members who may be interested are invited to get into touch with the Secretary of their nearest group, namely:

New South Wales Group
Mr. J. M. Smail, 9, Dalkeith Street, Northbridge, New South Wales.

South Australian Branch
Mr. A. B. Fuss, Virginia, South Australia.

Victoria Group
Mr. S. Scott-Hall, 9 Laurel Court, Hawthorne E.3, Victoria.

Members visiting Australia might also like to contact one or more of the groups, who would welcome their attendance at the meetings.

Private Discussion Meeting on British Astronautics

A private discussion meeting on British Astronautics was held recently. It was attended by Members of Council and the special panel mentioned in the Chairman's Address for 1959 (*J.B.I.S.*, 1959-60, **17**, 412). Speakers from various ministries, the Parliamentary Committee on Space, and a space research group addressed them and views were exchanged on possible future developments.

Grants for Travel to America

UNESCO has made available to the International Astronautical Federation a sum of money to be used to assist young scientists to travel to Washington, D.C., to attend the XIIth Congress of the Federation to be held there during the first week of October, 1961. The Society has been asked to submit the names of three candidates to be considered for financial assistance; candidates should not be over 30 years of age and their work should have a direct bearing on astronautics.

As the Society has to submit names and supporting information to the I.A.F. Committee by 15 June, any persons who wish to be considered are asked to apply immediately to the Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, S.W.1 (TATe Gallery 9371), from whom further particulars can be obtained.

Abstracting Panel

Several offers of assistance were received in response to the request in the February, 1961, issue of the *Journal* for members to join the abstracting panel. These offers are greatly appreciated and have been accepted, but more abstractors are still required, particularly for astronomy and space physics. Members who would be willing to undertake the abstracting of one or more periodicals are asked to inform the Editor (1, Herbert Road, Hornchurch, Essex) of the subjects in which they specialize and which languages they can read.

Lecture Programme

The Lecture Programme for the second half of the 1961 session is now being drawn up. The increased activity that is a feature of the present half-session is being maintained and it is hoped to include further one-day symposia and joint meetings with other bodies. An innovation which should prove welcome is that this year's Annual General Meeting will be followed by a Presidential Address.

Lecture notices announcing the meetings and symposia will be prepared, and it is hoped that they will be displayed as widely as possible. Those who can display posters or assist in other ways (*e.g.*, by including notes in staff or college magazines) are invited to do so. The posters and copies of symposia programmes, etc., are obtainable on request from the Secretary, who will be pleased to provide any further help or information.

Commonwealth Spaceflight Symposium

The Proceedings of the First Commonwealth Spaceflight Symposium, organized by the Society in 1959, have now been published as *Spaceflight Technology*, edited by Kenneth W.

Gatland (Academic Press, December, 1960, 75s.). Copies may be purchased from the Interplanetary Publishing Company, 12, Bessborough Gardens, London, S.W.1.

Arrangements for holding the Second Commonwealth Spaceflight Symposium are now under consideration.

Income Tax Relief for Annual Subscriptions

The Society is approved by the Commissioners of Inland Revenue for the purposes of Section 16 of the Finance Act, 1958, so that members who qualify for relief under that Section are able to claim the whole of their annual subscription as a deduction from their emoluments assessable to income tax under Schedule E, and should apply to their tax offices for Form P358 on which to make a claim for adjustment of their P.A.Y.E. coding. It is not necessary to produce a receipt for the payment of the subscription.

Benevolent Fund

Contributions to the Benevolent Fund received during 1960 amounted to £277 15s. 5d. and the balance of the Fund at the end of the year amounted to just over £1142, so that we are now over one-third of the way towards the target of £3000 which has always been considered to be the minimum necessary to establish the Fund on a firm basis. The Trustees and the Council of the Society wish to express their thanks to all who have already contributed to the Fund.

However, further contributions are required. It should be borne in mind that the sum already received includes a grant of £750 from the general funds of the Society. This was intended to serve as a nucleus for the Fund in its initial years; although the possibility of further such grants in the future is not to be ruled out the Society has heavy commitments to meet in other directions and is unlikely to be in a position to make a similar payment for some years at least.

The Trustees will therefore welcome further contributions from members and others, and particularly wish to draw to their attention the advantage to the Fund of contributions made under covenant. In this scheme the member completes a Deed of Covenant in which he undertakes to remit a certain stated amount each year for a minimum period of 7 years and in so doing, enables the Trustees to claim a refund of income tax paid by him. This involves no additional obligation on the member concerned but provides extra income for the Fund. Should the member die before the end of the 7 years, all obligation under the Covenant ceases.

Council would like to stress that the Benevolent Fund is a useful objective of the Society and deserves continued and increased support. The Trustees have already made a grant of £50 to the widow of a member, and sent wreaths in other cases. They are ready to consider making other grants from the Fund to alleviate distress caused to members or their dependents by disablement or bereavement, etc., and would be grateful if cases meriting consideration could be brought to their notice.

Initially, any member of the Society of more than 5 years' standing (or his or her dependents) is eligible for assistance. Benefits from the Fund are not restricted to members in the United Kingdom or Commonwealth.

Contributions should be sent to the Secretary, B.I.S. Benevolent Fund, 12, Bessborough Gardens, London, S.W.1, from whom forms for Deeds of Covenant and advice concerning clauses for inclusion in Wills, etc., are obtainable.

Donations to the Fund from firms engaged or interested in astronautics are also welcomed; these will be acknowledged individually in the *Journal*. Members, whether in Britain or abroad are requested to bring this appeal to the notice of the employers.

Election of Members

The following elections were made at the Membership Committee Meeting held on 7 July, 1960:

New Fellows.

KENNETH JAMES BALL, B.Sc., 13, Princess Close, East Cowes, Isle of Wight.
HAROLD BERGER, B.S., L.L.B., 605, West Arbutus Street, Philadelphia, Pennsylvania, U.S.A.
ROGER BOWER-BROWN, B.E., A.M.I.Mech.E., 29, Oppidans Road, London, N.W.3.
STEVEN CAP, M.S., 85, Cedar Drive, Farmingdale, Long Island, New York, U.S.A.
DENNIS QUINTRELL FULLER, A.M.I.E.E., 48, Metcalfe Road, Cambridge.
RONNIE JACOBSON, B.S.E.E., 1785, Bermuda Lane, El Cajon, California, U.S.A.
ROLAND BERTRAM MANNERS, A.M.I.Mech.E., A.F.R.Ae.S., 69, Clipstone Crescent, Leighton Buzzard, Bedfordshire.
ROBERT ST. CLAIR SWANSON, B.S., 4641, Hayvenhurst Avenue, Encino, California, U.S.A.
GERALD EDWARD TAYLOR, B.S., 262, Procop Avenue, Jericho, New York, U.S.A.
KENNETH WILLIAM TUCKER, Trials Establishment, Guided Weapons, Royal Artillery, Ty Croes Camp, Anglesey.

Members elected to the Fellowship.

NORMAN ROBSON NICOLL, 93, Leighswood Avenue, Aldridge, South Staffordshire.
MICHAEL JACOB WORTH, A.M.I.Mech.E., P.O. Box 1221, Nairobi, Kenya.

New Associate Fellows.

JOSEPH WAYMAN DUNCAN, 10 Irving Street, Lowell, Massachusetts, U.S.A.
RAYMOND EDWARD MATTHEWS, 74, Gonville Crescent, Stevenage, Hertfordshire.
PETER ROBERTS, 23, Breck Road, Winton, Eccles, Manchester, Lancashire.
DONALD EDWIN RYAN, B.A., 3309, Grooms Apt. 202, Austin, 5, Texas, U.S.A.
HOWARD CHARLES TINNEY, B.S., 11336, Riviera Place N.E., Seattle 55, Washington, U.S.A.

Members elected to Associate Fellowship.

WILLIAM PATRICK ADAMS, M.E., 891, N. Ohio Street, Arlington 5, Virginia, U.S.A.
IAN LEONARD MCLAUGHLIN, B.Sc., 9, Auburn Avenue, Myrtle Bank, c/o Parkside P.O., S.A., Australia.
DAVID GEORGE STRATTON, B.A., Air B.P., B.P. Trading Limited, Ropemaker Street, London, E.C.2.

New Members.

JOHN ALEC BIGGS-DAVISON, M.A., M.P., 14, Lennox Gardens Mews, London, S.W.1.
PIETER JAN BRUIJN, Diedenweg 61, Wageningen, The Netherlands.
GEORGE DAVIS CAUSEY, 817C, 14th Street, Santa Monica, California, U.S.A.
HERBERT B. HAAKE, B.M.E., General Electric Co., Bldg 28–504, Schenectady, New York, U.S.A.
MELVILLE LESTER HARLAND, 123, Centaurus Road, St. Martins, S.E.2., Christchurch, New Zealand.
JOSEPH EDWARD HENDRICKS, 3536, Orchard Lane, Hopkins, Minnesota, U.S.A.
DENYS FREDERICK HIBBINS, 12, Howbury Road, Nunhead, London, S.E.15.
JAMES JOHNSTON INGLIS, 27A, High Street, Girvan, Ayrshire, Scotland.
PAUL ERIK KOSKELA, B.S., 1716, Westcliff Drive, Newport Beach, California, U.S.A.
JEAN MEEUS, 65, Bergstraat, Kessel-Lo, Belgium.
PAUL GEOFFREY MURDIN, 92, Northborough Road, London, S.W.16.
JOHN FRED POTTER, B.Sc., Maison du Cuba, Cité Universitaire, Paris, France.
LESLIE WALTER V. RAYBOULD, 84, Hersham Road, Walton-on-Thames, Surrey.
ALAN JAMES TOUCH, 2000 Bates Avenue, Springfield, Illinois, U.S.A.
HERBERT WYNDHAM WILLIAMS, Bonvilston Cottage, Bonvilston, nr. Cardiff.

The following elections were made at the Membership Committee Meeting on 4 August, 1960:

New Fellows.

TATOMIR ANGELITCH, Ph.D., Belgrade, Strahinica Bana, 74/11, Yugoslavia.
STANLEY ARTHUR GOLDEN, B.S., Ph.D., 18564, Clark Street, Tarzona, California, U.S.A.
CHARLES HUGH MILLER, M.Sc., 56, Dene Hall Drive, Bishop Auckland, Co. Durham.
DEWITT O'KELLY MYATT, 1, Bolling Road, Alexandria, Virginia, U.S.A.
ERVIN DAYLE THORSON, M.A., 142A, San Vicente Boulevard, Santa Monica, California, U.S.A.

Members elected to the Fellowship.

DANIEL BROWN DEBRA, B.E., M.S., 1421, Meadow Lane, Mountain View, California, U.S.A.
ROBERT M. PAGE, M.S., Ph.D., 16844, Bollinger Drive, Pacific Palisades, California, U.S.A.

New Associate Fellows.

PETER HENRY DWIGHT, 30, Ludlow Way, Croxley Green, Rickmansworth, Hertfordshire.
RICHARD JAY LEVY, A.B., 26, Hubbard Avenue, Cambridge 40, Massachusetts U.S.A.

Members elected to Associate Fellowship.

JOHN STUART BEVAN, B.A., 136, The Fairway, South Ruislip, Middlesex.
SAMUEL RAYWORTH DAUNCEY, B.A., 32, Belmont Road, Twickenham, Middlesex.

Members elected to Senior Membership.

MALCOLM EDWARD LAURIE, 276, High Street, Walton, Felixstowe, Suffolk.

New Members.

WILLIAM FRANCIS LANCE BAKER, 66, Rudford Close, Woodland Estate, Patchway, Nr. Bristol.
DAVID ARCHER BRIDGEMAN, Block 55, Royal Air Force, Digby, Lincolnshire.
JAMES G. CAUGHRAN, 2650, Durant Avenue, Berkeley 4, California, U.S.A.
PETER ELLIOTT, 6, Carlton Terrace, St. Judes, Plymouth, Devon.
PIERRE-MARIE-RICHARD GALLOIS, 8, Rue Rembrandt, Paris, 8, France.

ROBERT JOHN GANDERSON, 727B, Green Lanes, Winchmore Hill, London, N.21.
DONALD CEDRIC GLYNN, "Ryedale," 279, Chapeltown Road, Leeds, 7.
WILLIAM GEORGE GREEN, c/o 8, Grosvenor Road, Hounslow, Middlesex.
EDWARD SYDNEY HAYNES, 156, Shadwell Lane, Leeds, 17, Yorkshire.
JOHN TURTON KEETON, 44, Brooms Road, Dumfries, Scotland.
GRATTAN HENRY LYNG, 372, Evan's Bay Road, Wellington, New Zealand.
GRAHAM FRANCIS MAHON, 7, Greig Street, Seddon W.11, Melbourne, Victoria, Australia.
HON. PATRICK MAITLAND, B.A., 10, Ovington Square, London, S.W.3.
CARDON GRAFTON ROSS, 16, Belsize Crescent, Hampstead, London, N.W.3.
GARETH LLOYD WILLIAMS, Jolly's Bottom Farm, Chacewater, Truro, Cornwall.

New Corporate Member.

A.T.S. CO. LTD., 18, St. James's Square, London, S.W.1.

The following elections were made at the Membership Committee Meeting on 13 October, 1960:

New Fellows.

NORMAN WILLIAM BOORER, A.F.R.Ae.S., Nook Cottage, Blackhorse Road, Crastock, Woking, Surrey.
SANDERSON BUCHANAN, B.Sc., A.M.I.Mech.E., A.F.R.Ae.S., 95, Villiers Avenue, Surbiton, Surrey.
WALTER RALPH CLARK, 1573, Larkin Avenue, San Jose, California, U.S.A.
VIRGIL N. COMSA, M.S., 1550 E. Marbury, West Covina, California, U.S.A.
ERNEST WALTER ELLIOT, A.M.I.E.E., 28, Rockley Court, Rockley Road, London, W.14.
JOHN DUNCAN HILCHEY, B.S., Ph.D., 68, Leigh Street, Framingham, Mass., U.S.A.
JAMES REGINALD BENTINCK HINTON, c/o Qatar Petroleum Co. Ltd., P.O. Umm Said, Dukhan, Persian Gulf.
ANDREW GORDON HOLMES-SIEDLE, B.A., Ph.D., Astronautics Division, Advanced Projects Group, Hawker-Siddeley Aviation, Richmond Road, Kingston-on-Thames.
FRANKLIN GEORGE KELLY, B.S., 22, Hilltop Avenue, Wilmslow, Cheshire.
MELVIN RICHARD MESNARD, B.S., 625, Houseman Street, La Canada, California, U.S.A.
PETER JOHN REEN, 30, Uphill Grove, Mill Hill, London, N.W.7.
JOHN ALEXANDER RITCHIE, A.M.I.Mech.E., A.F.R.Ae.S., 54, Blackpool Road North, St. Annes on Sea, Lancashire.
DHIRENDRA NARAYAN ROY, M.B., Garh Pakma Basan, Rajvawan, Tamluk, India.
DAVID GORDON WILSON, B.Sc., Ph.D., c/o Northern Research & Engineering Corporation, Mercury House, 195, Knightbridge, London, S.W.7.

Members elected to the Fellowship.

PIERRE-MARIE GALLOIS, 8, Rue Rembrandt, Paris 8, France.
JOHN RICHARD MILLBURN, B.Sc., 58, BIERTON ROAD, Aylesbury, Buckinghamshire.

New Associate Fellows.

JAMES JOSEPH BALTES, B.S., 1546, Englewood Avenue, Saint Paul 4, Minnesota, U.S.A.
NEVILLE JAMES BARTER, 5901, Clint Place, Palos Verdes Estates, California, U.S.A.
BRYAN PHILIP DAY, B.Sc., Farnborough Grange Hostel, Farnborough, Hampshire.
JULIUS GEORGE GULACK, B.S., 19, Fletcher Street, Essendon, W.5, Melbourne, Victoria, Australia.
DOANLD JOHN HILTON, B.Sc., 77, Southdale Road, Rock Ferry, Birkenhead, Cheshire.
JOHN ARTHUR HODGKINS, 9, North Street, Smethwick, Staffordshire.
HUGH GAVYN JENKS, Assistant Military Attaché, British Embassy, Strandvagan 82, Stockholm, Sweden.
JAMES REDMON JORDAN, 9, Haliburton Road, East Twickenham, Middlesex.
ROGER LAYTON LEIGHTON, P.O. Box 349, Awali, Bahrain Island, Persian Gulf.
THEODORE JOSEPH LIVESAY, B.S., Headquarters, 1st Battle Group, 11th Infantry, Fort Benning, Georgia, U.S.A.
WILLIAM HERBERT LORD, G.I.Mech.E., 2, Lynfield Road, Great Harwood, Lancashire.
FRANK OGDEN, 34, Rockingham Way, Stevenage, Hertfordshire.
GODFREY THOMAS JOHN PULLAN, M.A., The White House, 16, Minley Road, Cove, Farnborough, Hampshire.
HENRY SHAWBROOK, A.R.Ae.S., Clifton House, 10, Southside, Wimbledon, London, S.W.19.
EDWARD HENRY SMITH, 134, Southover, Bromley, Kent.
GEOFFREY JOHN STURGESS, D.L.C., Grad.R.Ae.S., 62, Wyvern Avenue, Leicester.
KENNETH JOHN TURNER, B.Sc., 88, West Dumpton Lane, Ramsgate, Kent.
PREMARATNE GUNASINGHA WALPITA, B.Sc., 49, Palmgrove Avenue, Ratmalana, Ceylon.
RONALD GEORGE WIGGINS, 85, Paul Revere Road, Arlington, Mass., U.S.A.

Members elected to Associate Fellowship.

BRIAN EDWARD GILL, 13, Manor Road, London Colney, Hertfordshire.

Members elected to Senior Membership.

JAMES ALAN BROWN, 26, Heybridge Avenue, London, S.W.16.

New Members.

ARTHUR WILLIAM BARTON, c/o Post Office, Woomera West, South Australia.
HENRY BAYLEY, 18, Walton Heath Road, Stockton Heath, Warrington, Lancashire.
EDWIN MALCOLM BERESFORD, 3, Birdview Square, Feltwell, Thetford, Norfolk.
RAINER BLUM, Muelheim/Ruhr, Oberstrasse 96, West Germany.
ERNEST RICHARD BROADFIELD, B.Sc., 137, Hill Village Road, Four Oaks, Sutton Coldfield, Warwickshire.
WILLIAM JOSEPH BROWNING, Mould & Engineering Co. Ltd., Ashtead, Surrey.
KENNETH RONALD CAREW, 29, Grosvenor Road, Southall, Middlesex.
JAMES SAMUEL CHITTENDEN, 2, Church Path, Farnborough, Hampshire.
DAVID JOHN CLAYE, 35, Old Lane, Bloxwich, Walsall, Staffordshire.
HAROLD GRINDLEY COLEBOURN, Ruskinville, Little Switzerland, Douglas, Isle of Man.
DAVID CHARLES ARTHUR COOPER, 7, Bonham Gardens, Dagenham, Essex.
DENIS LYN DAVIES, "Trallwn," 31, Belvidere Walk, Shrewsbury, Shropshire.
EDWIN WILFRED DAVIES, 4, Winsley Road, Bradford-on-Avon, Wiltshire.
ELIZABETH DE TAUBE, 14, Brechin Place, London, S.W.7.
ANTOINE DU BOURG, B.A., Pingry School, Elizabeth, New Jersey, U.S.A.
ALBERT ENTICKNAP, Guibal House, 50, Guibal Road, Lee, London, S.E.12.
NILS ARVID ESTENSTAD, "Valentinelyst," Ladenita, Strinda, Norway.
MICHAEL JAMES EVASON, 57, Adela Avenue, New Malden, Surrey.
WILLIAM HOPE FENN, P.O. Box 127, Auckland C.I., New Zealand.
CHARLES FRANCIS FIELD, 2, Popular Avenue, Bergvliet, Cape Town, South Africa.
ALAN FITTON, 62, Roch Mills Crescent, Brimrod, Rochdale, Lancashire.
CHRISTOPHER FRANK FOUNTAIN, 23, Lingfield, Sidmouth Street, London, W.C.1.
SUN-KWAN FUNG, 145, Mansel Street, Balornock, Glasgow, N.1.
LESLIE GREEN, 34, Overlea Road, London, E.5.
ALAN DAVID GRIFFITHS, 70, Water Orton Road, Castle Bromwich, Warwickshire.
GEORGE DUNNE CAMERON HOSKING, 21, Kersland Street, Glasgow, W.2.
DAVID GEORGE JONES, 22, Manor Road, Hampden Park, Eastbourne, Sussex.
AVRIL BEATRICE KNIGHT, 113A, Bushey Hill Road, Camberwell, London, S.E.5.
BEREND KUIPER, 29, Avenue Wendt, Geneva, Switzerland.
PETER ARTHUR LLOYD, 2, Duncroft Manorfarm Estate, Dedworth, Windsor, Berkshire.
KUMUD KUMAR MAJUMDER, M.B.B.S., A.M.E., c/o R.A.F. Institute of Aviation Medicine, Farnborough, Hampshire.
MICHAEL ANTHONY MCDERMOTT, Y.M.C.A. Hostel, Lostock Dene, Lostock, Bolton.
KENNETH JOHN MILTON, B.A., 1, Greenfield Street, Aberystwyth, Cardiganshire.
ANTHONY REUBEN PACE, 133, Newlands Street, Shelton, Stoke-on-Trent, Staffordshire.
CYRIL PICKARD, 378, Milton Road, Cambridge.
CLIFFORD EDWARD RAWSTON, 64, Long Road, Lowestoft, Suffolk.
COLIN PETER RICHARDS, 5, Monument Road, Helston, Cornwall.
SAMUEL CHARLES RICHARDSON, 115, E. Aspen Street., Flagstaff, Arizona, U.S.A.
SAMUEL RITCHIE, 33, Caldew Street, Silloth, nr. Carlisle, Cumberland.
DAVID CHRISTOPHER ROBERTS, Y.M.C.A. Montgomery House, Moss Side, Manchester.
CLIFFORD NORTON ROGERS, 78, Harlow Terrace, Harrogate, Yorkshire.
RENATE SCHLAEGER-PRIESING, 13, Boelckestrasse, Hannover, Germany.
OLGA SOUBBOTINE, 14, Brechin Place, London, S.W.7.
ROGER THRUSH, 23, Clevedon Gardens, Cranford, Middlesex.
WILLIAM WEBSTER, 46, Hillhead Crescent, Motherwell, Scotland.
JAMES ALBERT YOUNG, P.O. Box 381, Hennepin, Illinois, U.S.A.

The following elections were made at the Membership Committee Meeting on 1 November, 1960:

New Fellows.

THOMAS GEORGE JEFFREY DYER, B.Sc., 13, Dean Rogers Place, Braintree, Essex.

New Associate Fellows.

ALEXANDER CONNELLY, c/o 24, Derwent Drive, Hayes End, Middlesex.
GEOFFREY HARRY COX, 208, Brixton Road, London, S.W.9.
WILLIAM JAMES GATEHOUSE, c/o Officers Mess, H.Q. R.A.F. Germany, B.F.P.O. 40.
JOHN ALEXANDER PURVES GLEN, 57, Devonshire Road, Bristol 6.
JOHN LESTER RUDKIN, 34A, Neeld Crescent, Wembley, Middlesex.

New Members.

JOHN EDMUND DALE, 9, Holmesdale Road, Kew Gardens, Surrey.
PHILIP GEORGE HALL, 36, Station Road, Polesworth, Tamworth, Staffordshire.
CHRISTOPHER JOHN ALEXANDER HAWKER, 6, Priory Road, Keynsham, nr. Bristol.
GEOFFREY FRANK JOHNSTONE, 10A, Lillington Avenue, Leamington Spa, Warwickshire.
MICHAEL FREDERICK PACE, 133, Newands Street, Shelton, Stoke on Trent, Staffordshire.
EDWARD ROGER WATERWORTH, B.Sc., 2, Waxlow Crescent, Southall, Middlesex.

The following elections were made at the Membership Committee Meeting on 6 December, 1960:

New Fellows.

GEORGE HURST RANDLE, B.A., M.I.E.E., Frogmore Hall, Watton-at-Stone, Hertfordshire.

Members elected to the Fellowship.

ARTHUR CONRAD FITZGERALD, A.M.I.M.M., c/o The Ex-Lands Nigeria Ltd., P.O. Barakin Ladi, Northern Nigeria, West Africa.

New Associate Fellows.

JOHN MCDOWELL, "Eastfield," 75, The Grove, Marton, Middlesbrough.

New Members.

DONALD CHARLES COONFIELD, P.O. Box 702, Clovis, New Mexico, U.S.A.
JOSEPH C. LITTLEFIELD, M.Sc., Box 737, Cocoa Beach, Florida, U.S.A.
GEORGE IAN MIDDLETON, 19, Burwell Street, Paris, Ontario, Canada.
RANDALL ALEXANDER SNOWDON, 149, Cowley Road, Uxbridge, Middlesex.
AUBREY WILLIAM TREDDLE, Selwyn House, St. Matthews Hospital, Burntwood, Lichfield.

The following elections were made at the Membership Committee Meeting on 24 January, 1961:

New Fellows.

HILDREY ISODORE BEMENT, M.A., 1794, Wright Street, Pomona, California, U.S.A.
ANTHONY BASIL CARTER, Greenaleigh, Pen-Y-Bryn, Brecon, South Wales.
LAURENCE GEORGE STANLEY CLARK, B.Sc., A.Inst.P., A.M.I.E.E., "Coopers," California Lane, Bushey Heath, Hertfordshire.
JOHN ERNEST PATRICK DUNNING, M.A., Church Farm House, Westcott, Aylesbury, Buckinghamshire.
Group Capt. EDWARD FENNESSY, C.B.E., B.Sc., M.I.E.E., Red Lodge, Goddington Lane, Orpington, Kent.

BERTRAM ROLAND GRANTHAM, "Elswick," 14, Mount Crescent, Tupsley, Herefordshire.
BRYAN HAROLD GREAVES, B.Sc., 21, Padwick Avenue, Cosham, Portsmouth, Hampshire.
PETE IRVIN, B.Sc., A.M.I.E.E., 21, Cherry Hill, St. Albans, Hertfordshire.
LEONARD FREDERICK MATHEWS, M.Brit.I.R.E., 89, Shepherds Lane, Dartford, Kent.
DONALD FRANK MCALLISTER, B.Sc., 4709, Rockbluff Drive, Rolling Hills Estates, Los Angeles, California, U.S.A.
PETER NEUBAUER, B.Mech.E., 818, W. Crockett Street, Seattle 99, Washington, U.S.A.
COSTAS ERNEST PAPPAS, M.S., Deer Park Road, RFD 4, Dix Hills, Huntington, Long Island, New York, U.S.A.
RICHARD CHARLES READ, D.L.C., Pine Cottage, Kings Lane, Windlesham, Surrey.
ROBERT E. RICLES, B.Aero.E., 526, Cedar Street, West Hampstead, Long Island, New York, U.S.A.
JANN SEDDON, B.Sc., D.C.Ae., A.M.I.Mech.E., 9, Dale Close, Hitchin, Hertfordshire.
LEONARD I. SHERRY, B.A., 89, Cornell Lane, Hicksville, Long Island, New York, U.S.A.
MALCOLM HAROLD SINGER, M.B.Ch.B., 10, Eltham Hill, Eltham, London, S.E.9.
CORNELIUS JACOBUS ZILVERSCHOON, D.Sc., 2B, Clos Ou Midi, Grand-Lancy, Geneva, Switzerland.

New Associate Fellows.

RONALD LEGRAND ARMS, M.S., 2905, Valley Drive, Manhatten Beach, California, U.S.A.
BRYAN EDWARD BARRY, B.Sc., 4A, Coates Gardens, Edinburgh, 12.
JABEZ ARTHUR GEORGE BEADLE, A.F.R.Ae.S., 1, Brambletree Crescent, Borstal, Rochester, Kent.
JOHN CLIFFORD CAIN, M.Sc., 63, Park Road, London, W.4.
FREDERICK ANTHONY FORSYTHE CLARKE, 17, Ravensmere Road, Redditch, Worcestershire.
JOHN MORRIS CLUBLEY, G.I.Mech.E., 1, Haddon Court, Hatfield, Hertfordshire.
PETER DUGAN, 5, Alexander Grove, Fareham, Hampshire.
DAVID PETER JOHN EASTON, G.I.Mech.E., 30, Hampshire Street, Fratton, Portsmouth, Hampshire.
BERNARD HAROLD FEATHERSTONE, 94, Colvestone Crescent, Dalston, London, E.8.
LAURI HALL HILLBERG, B.Aero.E., 29645, South 10th Place, Federal Way, Washington State, U.S.A.
FRANCES DOTTIE RANDALL, B.S., Rt.2., Box 6368, Issaquah, Washington, U.S.A.
JOHN RYLAND WILLIAMS, B.Sc., 76, Tirycoed Road, Glanamman, Ammanford, Carmarthenshire, South Wales.
WILLIAM ALEXANDER AUBREY WITHAM, 4, Kennel Lane, Bracknell, Berkshire.

Members elected to Associate Fellowship.

JOHN PAUL DAVIS, B.S., 650, Branch Street, San Luis Obispo, California, U.S.A.
GEOFFREY NAPIER DENCE, B.Sc., 6, Embry Way, Stanmore, Middlesex.
NICHOLAS NEWMAN, B.E., c/o A.N.Z. Bank, 263, Strand, London, W.C.2.
RENZO DAVID STORTI, 13, Craigmillar Avenue, Milngavie, Glasgow.

Members elected to Senior Membership.

FRANK MURRAY AMBLER, 16, Ethelred Road, West Worthing, Sussex.
PETER CHARNLEY, 21, Scarisbrick Avenue, Southport, Lancashire.
WILLIAM FLINT MACDONALD, Alichenlarich, by Alexandria, Dunbartonshire, Scotland.
NORMAN PHILIP ROBINSON, 27, Cherry Holt Avenue, Heaton Mersey, nr. Stockport, Cheshire.

New Members.

STANLEY EDWARD AGOMBAR, 4, Emu Court, Norlane Via Geelong, Victoria, Australia.
STUART JAMES ASHILL, c/o 61, Glamis Crescent, Hayes, Middlesex.
JOHN KENNETH BARNFIELD, 1, Dorset Avenue, Rowanfield, Cheltenham, Gloucestershire.
STEPHEN C. BROMLEY, 107, Graduate College, Princeton University, Princeton, N.J., U.S.A.
RUSSELL GEORGE VICTOR BROTHERTON, 8, Bell Lane Cottage, White Lion Road, Amersham, Buckinghamshire.
JEFFREY R. BROWN, 57, Chesham Road, Penge, London, S.E.20.
RICHARD GEORGE DIGBY CHAMBERLAIN, B.A., Lyth House, Ringland Lane, Old Costessey, Norfolk.
JOHN SWANN CHARLTON, 23, Bishops Meadow, Bedlington, Northumberland.
ALLAN BARRY CHICK, "The Gardens," Pyrford Court, Woking, Surrey.
ROBERT WILLIAM DOWNES, 45, Deans Way, Ash Green, Exhall, nr. Coventry.
KNUT STALE ECKHOFF, Valandsgt 68, Stavanger, Norway.
KAZIMIERZ PAUL FILIPEK, 43, Regent Street, Kincardine-on-Forth, by Alloa, Scotland.
JOSEPHINE UNDERWOOD GOODALE, 607 Oronoco Street, Alexandria, Va., U.S.A.
IAN MICHAEL GUBBINS, Flint Cottage, White Horse Lane, Elham, nr. Canterbury, Kent.
COLIN ANTHONY EMIL HAMMETT, 365, Whitton Dene, Isleworth, Middlesex.
ALAN ERNEST GWYNN HAWKINS, 50, Middle Lane, Hornsey, London, N.8.
PETER MELROSE HOWARTH, 6, Methven Drive, Dunfermline, Fife, Scotland.
ROBERT ARMER LESLIE, 72, Rosehill Park West, Sutton, Surrey.
ANTHONY JOHN LUND, 10, Forbes Drive, Beccles, Suffolk.
MICHAEL ST. JOHN MACLEOD, 34, Silchester Road, St. Leonards-on-Sea, Sussex.
JAMES ARTHUR MAXWELL, B.A., 36195, Mission Boulevard, Fremont, California, U.S.A.
GERALD FRANCIS ROBERT CLIVE MORRIS, c/o Staff Mess, Woomera, South Australia.
REINER FRANZ NAWRATH, Düsseldorf, Ahnfeldstrasse 87, Germany.
FRANKLIN JOSEPH NIEDZ, B.S., 336, Gates Street, Philadelphia 28, Pennsylvania, U.S.A.
WILLIAM GLASS NOBLE, 73 Towerhill Road, Knightswood, Glasgow, W.3.
GEOFFREY PARRISH, 87, Cambridge Street, Cleethorpes, Lincolnshire.
JOHN STANLEY PEARCE, 42, Sandringham Road, Wood Green London, N.22.
HANS-DIETER PERZ, Oberbachem ueb. Bad Godesberg, Hauptstrasse 26, Germany.
GEOFFREY WILLIAM RAYNER-CANHAM, 10, Castle Hill Avenue, Folkestone, Kent.
LEROY JOHN RYAN, M.S., 5300 W. Hutchinson Street, Chicago 41, Illinois, U.S.A.
DONALD THOMAS SCOFIELD, 118, Chatham Road, Battersea, London, S.W.11.
BO WALDEMAR THOTT, 5205, Falmouth Road, Washington 16, D.C., U.S.A.
HELEN OVERTON VIERLING WHITTINGTON, 1007, G. St., Alexandria, Va., U.S.A.
ALAN FARMER WOODHOUSE, 6, Homefield Close, Swanley, Kent.

New Corporate Member.

ELLIOTT BROTHERS (LONDON) LTD., Elstree Way, Borehamwood, Hertfordshire.

PERSONALITIES

Below are given some biographical details of three Members of Council who were elected at the last Annual General Meeting.

Dr. W. F. Hilton

William Frank Hilton was born in 1912 and educated at the Royal College of Science and the City and Guilds Engineering College. He graduated in physics and aeronautical engineering.

After spending 11 years building up the High Speed Wind Tunnel Section at the National Physical Laboratory, Teddington, he was posted to the U.S.A. to be Group Supervisor (Aerodynamics) of the Bumblebee Projects, Applied Physics Laboratory, Johns Hopkins University, and was responsible for the Terrier and Talos guided missiles.

After his return to England in 1950, he spent 9 years at Sir W. G. Armstrong Whitworth Ltd., as Chief Aerodynamicist, and in 1959 was transferred to the post of Head of Astronautics Division, Advanced Projects Group, Hawker Siddeley Aviation Ltd., at Kingston-upon-Thames. He is now building up a team of experts working full-time on space projects.

Mr. D. Hurden

Dennis Hurden was born in 1924 and educated at Uppingham and New College, Oxford, where he obtained an Honours degree in Engineering Science.

In 1944 he joined Armstrong Siddeley Motors Ltd., and was engaged on piston engine research and development. In 1946 he transferred to the newly-formed Rocket Section and remained with it through its expansion into a separate Division of the Company until 1957. During this period he was concerned with the development of the Snarler and Screamer aircraft rocket engines and with the early development of the Gamma power plant for Black Knight.

On his own admission, Mr. Hurden joined the British Interplanetary Society in 1947 as a means of getting the *Journal of the American Rocket Society*—one of the few

sources of information on rockets in those days. He became interested in the propulsion aspects of spaceflight and gave a number of lectures on the subject. As a result he found himself, somewhat to his surprise, elected to the Council of the Society, on which he has remained (with one break) for several years.

In 1957, Mr. Hurden left Armstrong Siddeley to become Assistant Chief Engineer of the Rocket Division, de Havilland Engine Co. Ltd., Edgware, and has recently become Research Manager of this company, which is now a member of the Hawker Siddeley Group.

Mr. G. K. C. Pardoe

Geoffrey Keith Charles Pardoe was born in London on 2 November, 1928, and educated at Wanstead County High School and Loughborough College, Leicestershire (1946-49). He obtained the Diploma of Loughborough College with First-Class Honours in Aeronautical Engineering and also obtained the B.Sc.(Eng.) degree of London University with Honours in Aeronautical Engineering.

Mr. Pardoe joined Armstrong Whitworth Aircraft, Armaments Division, Coventry, in 1949, and worked as Senior Aerodynamicist on Seaslug until September, 1951. He then moved to de Havilland Propellers Ltd., Hatfield, where he was in charge of the Aerodynamics Section working on Firestreak. His responsibility later included the Flight Analysis Section. In 1956 he was transferred to the London office of de Havilland Propellers Ltd. as Manager Project Office on the Blue Streak project. With the absorption of the company by the de Havilland Aircraft Co. Ltd. in 1960, he became Chief Weapons Research Engineer.

For 10 years Mr. Pardoe has been a Pilot Officer in the R.A.F. Volunteer Reserve. He also holds a Civil Private Pilot's license and is a member of the Ski Club of Gt. Britain.

JOINT ACTIVITIES

Joint Sounding Rocket Colloquium

A Joint Colloquium on Sounding Rockets is being organized by Société Française d'Astronautique, with the co-operation of Associazione Italiana Razzi and the British Interplanetary Society. It is to be held on Friday, **23 June, 1961**, at the Hotel Majestic, 23, Rue Laperouse, Paris 16e.

The Colloquium will be concerned with the sounding rocket itself, and not with data collected by the vehicle. The morning session will open at 9.00 a.m., the afternoon session will end at 6.00 p.m. About ten papers are to be presented.

The papers sponsored by the British Interplanetary Society are:

"Black Knight," by C. E. Tharratt (Chief Engineer, Saunders-Roe Division, Westland Aircraft Ltd.).

"The Application of Storable Propellents to Sounding Rockets," by D. Hurden and J. F. Knight (de Havilland Engine Co. Ltd.).

"Charge Characteristics of Sounding Rockets and Their Influence on External Ballistics," by J. A. Rolfe (Rocket Propulsion Establishment) and W. T. Fisher (Bristol Aerojet Ltd.).

Details of the provisional programme and other arrangements may be obtained from the Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, S.W.1.

European Symposium on Space Technology

A three-day symposium on Space Technology is being organized by the British Interplanetary Society and the Société Française d'Astronautique, with the co-operation of other European astronautical societies. It is intended primarily to bring together scientists, engineers, economists and politicians from Western Europe, to discuss the possibility of formulating a joint programme of space research.

The symposium will be held in the Council Room, Federation of British Industries, 21, Tothill Street, London, S.W.1, from Monday, **26 June**, to Wednesday, **28 June, 1961**, inclusive. Monday and Tuesday will be devoted to technical papers, Wednesday to a general discussion on European Collaboration.

The provisional programme is as follows:

Monday, 26 June.

9.00 a.m. *Registration.*

10.30 a.m. *Address of Welcome*, by Dr. W. R. Maxwell (President, British Interplanetary Society).

Morning Session.

Chairman: Dr. Theodore von Kármán (Chairman, Advisory Group for Aeronautical Research and Development, NATO).

10.45 a.m. Opening Remarks by Chairman.

11.00 a.m. "A New Type of Navigational Satellite," by G. J. Broussard (Compagnie Générale de Télegraphie sans Fil).

"The Scientific Necessity for a Rocket Network in Europe," by H. Faust (Deutscher Wetterdienst Zentralamt).

12.00 Discussion.

Afternoon Session.

Chairman: Professor I. Ranzi.

2.30 p.m. "Dynamics and Engineering of Satellite Attitude Control Systems," by B. Stewart and P. A. E. Stewart (Astronautics Division, Advanced Projects Group, Hawker-Siddeley Aviation Ltd.).

"The Attitude Control of an Astronomical Satellite," by J. R. Fell (Elliott Brothers (London) Ltd.).

3.30 p.m. Discussion.

4.00 p.m. "Digital Methods of Satellite Communications," by Dr. S. C. Ghose (E.M.I. Electronics Ltd.).

"Aerial Problems in Space Communication," by F. Charman (E.M.I. Electronics Ltd.).

5.00 p.m. Discussion.

Tuesday, 27 June.

Morning Session.

Chairman: Professeur E. A. Brun (Président, Société Française d'Astronautique).

9.30 a.m. "The Blue Streak Propulsion System," by A. V. Cleaver (Rolls-Royce Ltd.).

"Comparison entre les Systèmes d'Alimentation des Moteurs d'Engins Spatiaux," par L. Melin (Société d'Etude et de Réalisation d'Engins Balistiques).

10.30 a.m. Discussion.

11.00 a.m. "Influence du Ballottment des Liquides sur le Pilotage des Fusées Porteuses," par P. Polack (Société d'Etude et de Réalisation d'Engins Balistiques).

"Cryogenic Supply Facilities," by J. B. Gardner (The British Oxygen Company Ltd.).

"The Impact of Space Propulsion Technology on the Engineering Industry," by M. S. S. Hunt (Bristol Siddeley Engines Ltd.).

12.30 p.m. Discussion.

Afternoon Session.

Chairman: Air Marshal Sir Owen Jones.

2.30 p.m. "Application of Electric Propulsion to Satellite Control," by P. C. McNeill (Elliott Brothers (London) Ltd.).

"A Lightweight Solar Propulsion Unit for Transfer to a 24-Hour Orbit," by P. A. E. Stewart and J. F. Swale (Astronautics Division, Advanced Projects Group, Hawker-Siddeley Aviation Ltd.).

3.30 p.m. Discussion.

4.00 p.m. "Les Problèmes d'Optimisation des Vaisseaux Spatiaux Propulsés par Plasma," par M. Colombani (S.N.E.C.M.A.).

5.00 p.m. Discussion.

Wednesday, 28 June.

Morning Session.

Chairman: Airey Neave, M.P.

9.30 a.m. –1 p.m. Brief summaries of the following papers (amongst others) will be presented:

"Political and Economic Background to Space Co-operation," by David Price (Member of Parliament for Eastleigh).

"Space Engineering and European Collaboration," by Air Commodore F. R. Banks (Aerospace Technical Services Co. Ltd.).

"New Aerospace Technologies," by F. Vinsonneau (Société d'Etude et de Realisation d'Engins Balistiques).

"A European Space Programme," by Dr. L. R. Shepherd (Head of Research and Development, O.E.E.C. "Dragon" Project, United Kingdom Atomic Energy Authority).

Afternoon Session.

Chairman: To be announced.

2.30 p.m. –5 p.m. "Legal Problems Arising from a Co-operative Space Programme," by J. L. Weinstein (O.E.E.C. Nuclear Energy Agency).

"The Implications of Not Having a European Space Programme," by A. V. Cleaver (Rolls-Royce Ltd.).

"Practical Uses of Space Vehicles," by G. K. C. Pardoe (The de Havilland Aircraft Co. Ltd.).

"Co-operation between Europe and America in Advanced Technologies" (*provisional title*), by Dr. H. L. Dryden and A. W. Frutkin (National Aeronautics and Space Administration, U.S.A.)

"Australian Contributions to a European Space Programme," by H. J. Higgs (Weapons Research Establishment (Australia) Representative).

"Problems of Organization in Setting Up a European Space Programme" (*provisional title*), by Dr. Ir. C. J. Zilverschoon (C.E.R.N.).

Farewell Party

6.30–8.00 p.m. Farewell Cocktail Party to Overseas Guests. To be held in the Ballroom, St. Ermins Hotel, Caxton Street, London, S.W.1.

The official languages of the Symposium are English, French and German, and simultaneous translation equipment is being installed, so that both lectures and discussion will be available throughout in each of these languages. It is intended to provide preprints of the papers; where these are not in English, translations into English will also be undertaken if possible.

Arrangements have been made for professional conference interpreters to undertake the simultaneous translation service, but intepreters are also required to help with registration and general enquiries, and to translate papers for preprinting. Offers of assistance from linguists and from members prepared to act as stewards will be welcomed by the Secretary.

Members and others wishing to attend the Symposium are advised to apply as soon as possible, as attendance must be limited to 250. The registration fee for attendance at the symposium is £5 5s.; this will cover the provision of preprints. Tickets for the Farewell Cocktail Party are available, price 17s. 6d. for U.K. participants; oversea participants will be the

guests of the Society. Applications should be sent to the Secretary, British Interplanetary Society, 12, Bessborough Gardens, London, S.W.1.

International Symposium

An International Symposium on Spaceflight and Re-entry Trajectories is being organized by the International Academy of Astronautics of the International Astronautical Federation. It will be held at La Collinière, 9 Chemin de Prunay, Louveciennes, France (15 km. west of Paris) on **19-21 June, 1961**. The working languages in the meeting will be English and French, there will be no translation, but abstracts of the papers will be available in both languages. Further details are available from the Secretary, 12 Bessborough Gardens, London, S.W.1.

PERSONAL NOTES

Mr. L. J. CARTER (SECRETARY) has been elected to Extraordinary Membership of Deutsche Raketen-Gesellschaft e.V. and awarded the Society's Golden Badge.

Mr. DENNIS HURDEN, B.A., Grad.I.Mech.E. (MEMBER OF COUNCIL) has been appointed Research Manager, The de Havilland Engine Company, Ltd., a member of the Hawker Siddeley Group.

Wg. Cmdr. ANTONY STRUTT, O.B.E. (FELLOW) has retired from the Royal Air Force to take up the newly-created post of General Manager, Electrical Products Department, James A. Jobling and Company Ltd., Sunderland.

Mr. G. V. E. THOMPSON (MEMBER OF COUNCIL) has resigned his position as Senior Information Officer, The British Non-Ferrous Metals Research Association, and is to practise as a space technology consultant.

OTHER NEWS

Eight leading industrial firms are participating in the formation of the British Space Development Company, an organization to undertake the commercial exploitation of space. The firms are: Associated Electrical Industries, Associated Television, British Insulated Callenders Cables, Decca Radar, de Havilland, Pye Telecommunications, The Rank Organization and Rolls Royce, Ltd.

LECTURES

Seminar on Astronautics

In collaboration with AGARD, the University of Southampton is to hold a Seminar on Astronautics. It is intended to appeal to students from the United Kingdom and other European countries who graduate in engineering, mathematics or physics, and also workers in industry or research establishments who are engaged in one specialized branch of astronautics but are keen to gain more knowledge of associated fields. Lectures will be given by experts from the U.S.A., U.K. and continental Europe. Further details are obtainable from Dr. B. L. Clarkson, Department of Aeronautics and Astronautics, The University, Southampton, Hampshire.

The fee for the Seminar (including accommodation at a University Hall of Residence) is £21. Members of the British Interplanetary Society will be admitted free to the film show and Mr. Pardoe's lecture on the evenings of 13 and 17 July, respectively.

The tentative programme is as follows:

Wednesday, 12 July

Opening Lecture

Astronomy and Orbital Dynamics

"Orbits in the Solar System," by Dr. J. G. Porter.
"Space Navigation," by Capt. P. H. V. Weems.
"Earth Satellite Orbits," by D. G. King-Hele.
"Re-entry Orbits," by Dr. T. R. F. Nonweiler.

Thursday, 13 July

Aerodynamics

"Physical Properties of the Upper Atmosphere," by Professor E. Vassy.
"Hypersonic Aerodynamics," by K. N. C. Bray.
"Low-Density Test Facilities," by Professor R. L. Chuan.
"Physiological Limitations of Man in Space," by Flt.-Lt. J. C. Guignard.

Film Show at 8 p.m.

Friday, 14 July

Visits (half-day) to Radio Research Station, Slough, or to I.B.M. and the Plessey Co. Ltd.

Saturday, 15 July

Propulsion

"Operation and Control of Rocket Engines," by S. L. Bragg.
"Advanced Airbreathing Engines," by Dr. R. R. Jamison.
"Noise Problems at Launch and Re-entry," by Professor E. J. Richards.

Monday, 17 July

Structures

"Some Design Problems of Thin Shell Structures," by D. J. Johns.
"Optimization of Space Vehicles and Launchers Relative to their Mission," by Professor Fraeijs de Veubeke.
"A Method for Solving Non-Linear Thermal Problems in Re-entry of Space Vehicles," by Professor L. Broglio.
"Materials for Space Vehicles," by Professor A. J. Murphy.

Evening Lecture: "Spaceflight Projects Based on Blue Streak," by G. K. C. Pardoe.

Tuesday, 18 July

Guidance and Control

"Problems of Long-Range Detection and Tracking," by Dr. E. V. D. Glazier.
"Problems of Guidance in Astronautics," by Dr. A. W. Lines.
"Recent Advances in the Theory of Automatic Control," by Dr. J. K. Lubbock.

Visit to Royal Observatory, Herstmonceux (limited to 20).

Wednesday, 19 July

Visit to Royal Aircraft Establishment (Farnborough), G.W. Department.

ASTRONAUTICAL ABSTRACTS

Edited by J. HUMPHRIES

1961–62 PART 2

Abstracting panel:

C. FLEISHER, J. FOLEY, J. S. GRIFFITH, HAWKER SIDDELEY AVIATION LTD.; ADVANCED PROJECTS GROUP, C. E. S. HORSFORD, J. HUMPHRIES, A. E. SLATER, G. V. E. THOMPSON, E. WHITE

A complete list of journals abstracted together with abbreviations used is to be included in the 1959–60 index.

The following abstracts refer to books noted in this issue: 329, 343, 349, 432, 486, 553, 556-7, 560, 655-7, 691, 740.

1—ASTRONOMY

.2 *Stars and Nebulae*

(306) **Stellar astronomy from a space vehicle.** A. D. Cook. *Astronom. J.*, **65** (5), 278–284 (*June*, 1960). Observations needed for current astrophysical work.

.3 *Solar System, General*

(307) **Effects of the interstellar wind on the interplanetary plasma.** S. N. Milford. 11*th Internat. Astronaut. Congr.*, 6 pp. (1960). Interstellar gas passing through the solar system may affect the interplanetary gas, planetary atmospheres and satellite orbits. Interaction of the interstellar and interplanetary gases is considered; a solar system corona may be formed. (15 *refs.*)

.5 *Planets (except Earth)*

(308) **Miniature movies of the planets.** S. C. Baker and J. M. Kelso. *Astronautics*, **4** (5), 26–8, 104, 106 (*May*, 1959).
(309) **The ionosphere of Jupiter.** H. Rishbeth. *Austr. J. Phys.*, **12** (4), 466–8 (*Dec.*, 1959). Theoretical considerations suggest that Jupiter possesses an ionosphere with a critical frequency of ~ 20 Mc./sec., lying a few hundred km. above the level of the visible clouds.

.6 *Earth*

(310) **Investigation of the Earth's magnetic field with the aid of artificial Earth satellites and rockets.** N. V. Pushkov and S. S. Polginov. *Uspekhi Fizicheskikh Nauk*, **63**, 645–56 (1957). (*In Russian.*) (20 *refs.*)
(311) **Earth oblateness in terms of satellite orbital periods.** L. Blitzer. *Science*, **129**, 329–30 (6 *Feb.*, 1959). (3 *refs.*)
(312) **Vanguard measurements give pear-shaped component of Earth's figure.** J. A. O'Keefe, A. Eckels and R. K. Squires. *Science*, **129**, 365–6 (27 *Feb.*, 1959). (4 *refs.*)
(313) **Studies of the magnetic field of the Earth and Moon.** S. Sh. Dolginov, E. G. Eroshenko, Z. N. Zhuzgov, N. V. Pushkov and L. O. Tyurmina. 11*th Internat. Astronaut. Congr.*, 11 pp. (1960). Instrumentation used for magnetic field measurements on the first and second Soviet space probes, and results obtained. A difference of 7000 km. in the altitude of the maximum of the radiation belt near to the Earth was observed in the two flights. If the Moon has a magnetic field, its value at the lunar surface must be less than one-four-hundredth of the field at the Earth's surface. (7 *refs.*)

.7 *Moon*

(314) **On the origin of the Moon's surface features. Pt. I.** K. H. Engel. *J. Internat. Lunar Soc.*, **1**, 55–63 (*July*, 1958). (*Extensive summaries in Spanish, German and French.*) (6 *refs.*)
(315) **The other side of the Moon.** P. Moore. *New Scientist*, **4**, 650–3 (21 *Aug.*, 1958).
(316) **Prospecting the Moon without rockets.** Z. Kopal. *New Scientist*, **4**, 1052–3 (16 *Oct.*, 1958). An account of recent work on the properties of the Moon's surface.
(317) **Volcano on the Moon?** Z. Kopal. *New Scientist*, **4**, 1362–4 (27 *Nov.*, 1958). Discussion of a Russian lunar discovery.
(318) **A five-year plan of Moon research.** G. Fielder. *New Scientist*, **4**, 1571–3 (25 *Dec.*, 1958).
(319) **On the phenomena of the impact of a lunar projectile.** F. Link. *Bull. Astronom. Insts. Czech.*, **11** (2), 34 (1960). (*In French*). Effect of fall of rocket on to dust-covered lunar surface is discussed theoretically with emphasis on cloud produced. (3 *refs.*)
(320) **On the reverse side of the Moon.** A. A. Mikhailov. 11*th Internat. Astronaut. Congr.*, 4 pp. (1960). Method of photographing the reverse side of the Moon from *Lunik III* and televising the pictures back to the Earth; features observed on this side and comparison with those observable from the Earth. No satisfactory reason for the differences has been advanced.

.8 *Meteors*

(321) **Results of exploring meteoric matter with the instrumentation of *Sputnik III* and space probes.** T. N. Nazarova. 11*th Internat. Astronaut. Congr.*, 5 pp. (1960). Records of micrometeorite mass and energy ranges obtained with *Sputnik III*: and space probes I–III are presented. The density of meteoric matter in the vicinity of the Earth varies both in time and space.

2—PHYSICS

.1 *General*

(322) **The clock paradox.** W. F. Campbell. *Canad. Aeronaut. J.*, **4**, 316–9 (*Nov.*, 1958). Discusses this relativistic time-problem. (19 *refs.*)
(323) **Some physical properties for the system nitrogen tetroxide-nitric oxide.** D. B. Price and N. Fishman. *ARS J.*, **29** (5), 354–7 (*May*, 1959). (4 *refs.*)

.5 *Heat and Thermodynamics*

[*See also* abstracts nos. 480–1]

(324) **Experiments on porous-wall cooling and flow separation control in a supersonic nozzle.** L. Green and K. L. Nall. *Inst. Aeronaut. Sciences Repr.*, 59–38, 21 pp. (1959).
(325) **Recent developments in convective heat transfer.** R. H. Sabersky. *ARS J.*, **29** (5), 325–31 (*May*, 1959). (74 *refs.*)

.7 *Cosmic radiation*

(326) **Investigation of the composition of the primary component of cosmic radiation.** S. N. Vernov. *Uspekhi Fizicheskikh Nauk*, **63**, 131–47 (1957). (*In Russian.*) (8 *refs.*)
(327) **Measurement of cosmic radiation with the two artificial Earth satellites.** S. N. Vernov. *Dokl. Akad. Nauk S.S.S.R.*, **120**, 1231–3 (1958). (In Russian.) (3 *refs.*)

.8 *Other Upper Atmosphere Phenomena*

(328) **Some preliminary values of upper atmosphere density from observations of USSR satellites.** T. E. Sterne and G. F. Schilling. *Smithsonian Contributions Astrophysics*, **2**, 207–10 (1958).
(329) **The threshold of space.** M. Zelikoff. $15.00, 327 pp. *Pergamon Press, London and New York* (1958). Papers presented at the Conference on Chemical Aeronomy, 1956.
(330) **Army *Explorer IV* satellite reports corpuscular radiation intensity.** E. Clark. *Aviation Wk.*, **69** (4), 30–1 (4 *Aug.*, 1958).
(331) **The corpuscular radiation environment of the Earth.** S. F. Singer. *Paper V–10, Second International Congress of Rockets and Satellites, Paris* (1959).
(332) **Spectral measurements from a meterological satellite.** S. M. Greenfield and W. W. Kellogg. *Amer. Meteorological Soc. Symp. on Satellite Meteorology Paper* (4 *May*, 1959). Radiation scattered and emitted upwards depends on the distribution and temperature of atmospheric constituents with pronounced spectral absorption and emission bands: water vapour (infrared at 6·3 μ) and ozone (U.V. 0·2–0·3 μ; I.R. 9·6 μ), with CO_2 of less importance. The analysis shows how atmospheric changes may be estimated by spectral measurements in the U.V. and I.R. from a meteorological satellite.
(333) **The processing and analysis of satellite weather data.** W. W. Widger. *Amer. Meteorological Soc. Symp. on Satellite Meteorology Paper* (4 *May*, 1959). Programme planned for analysis of TV observation of clouds and radiometric measurements.
(334) **Satellite-measured radiation.** G. W. Stuart. *Phys. Rev. Letters*, **2**, 417–8 (15 *May*, 1959). (10 *refs.*)
(335) **The characteristics of the atmosphere. Pt. I. Pressure, density, temperature, chemical composition.** Israel. **Pt. II. Electrical state.** I. Ranzi. *Seminar in Astronautics and Space Sciences, Univ. of Rome* (18–29 *May*, 1959). (*In French.*)
(336) **Electrically charged bodies moving in the Earth's magnetic field.** W. W. Fain and B. J. Greer. *ARS J.*, **29** (6), 451–3 (*June*, 1959).
(337) **Study of the upper layers of the atmosphere by means of the third Soviet satellite.** V. [I.] Krasovski[i]. *Missili*, **1** (3), 37–43 (*June*, 1959). (*In Italian.*)
(338) **Optical determinations of atmospheric structure.** H. Friedman. 11*th Internat. Astronaut. Congr.*, 9 pp. (1960). Data on the variation of atmospheric chemical composition with altitude, obtained by rocket spectroscopy, are reviewed. A reflection echelle grating spectrograph being developed by the U.S. Naval Research Laboratory should have a resolving power of the order of 10^4. All of the high-resolution spectrographic work thus far has been photographic; adaption to electronic recording and telemetering offers no serious obstacles and would enable the absorption profiles to be obtained to heights of several thousands of miles.
(339) **Some problems of physics of the upper atmosphere.** V. I. Krassovskii. 11*th Internat. Astronaut. Congr.*, 12 pp. (1960). The formation of aurorae in the upper atmosphere is attributed to atmospheric penetration of electrons with energies of the order of 10 kV. Data obtained with *Sputnik III* are presented in support of this theory. (22 *refs.*)
(340) **The exploration of outer space.** S. N. Vernov. 11*th Internat. Astronaut. Congr.*, 10 pp. (1960). Summarizes the results of radiation measurements made with *Sputnik III* and space probes I–III. High-energy particles of the inner radiation belt near the Earth created artificially radioactive substances inside *Sputnik III*; it was found that the particles were protons with energies of about 10^8 eV. The origin of the radiation belts is discussed.

3—CHEMISTRY AND MATERIALS

.1 *General*

(341) **Materials for "hot" rocket parts must withstand 1700 deg. F plus.** R. C. Kopituk. *Aviation Age*, **28** (7), 104–9 (*Jan.*, 1958).
(342) **Structures and materials.** P. E. Sandorff. *Aviation Age*, **28** (9), 50–3, 59–60, 62–3 (*March*, 1958). A discussion of the subject with reference to manned spacecraft masses, protection and thermal resistance, and the new materials becoming available.
(343) **Materials for rockets and missiles.** R. G. Frank and W. F. Zimmerman. $4.50, 124 pp., *Macmillan Co., New York* (1959).
(344) **Material problems in space technology.** W. H. Steurer. *Third Symp. on Materials Res. in the U.S. Navy Prepr.* (1959).
(345) **Materials for astronautics vehicles.** A. J. Murphy. *Seminar in Astronautics and Space Sciences, Univ. of Rome* (18–29 May, 1959).
(346) **Behaviour of materials in space.** J. C. Simons. *Astronautics*, **4** (6), 32–3, 84, 86, 88 (*June*, 1959).

.2 *Chemistry*

(347) **The analysis of red fuming nitric acid. II. Determination of water by the Karl Fischer titration.** E. A. Burns and R. F. Muraca. *California Inst. Technology, Jet Propulsion Lab. Progr. Rept.*, 20–344, 8 pp. (*Jan.*, 1958).
(348) **Design and operating criteria for fluorine disposal by reaction with charcoal.** H. W. Schmidt. *N.A.S.A. Memo.* 1–27–59*E*, 18 pp. (*Feb.*, 1959). (3 *refs.*)

.3 *Metallurgy*

(349) **Metals for supersonic aircraft and missiles.** ed. D. W. Grobecker. 423 pp., *Amer. Soc. Metals, Cleveland, Ohio, U.S.A.* (1959).
(350) **Alloys and metal ceramics for high temperature service in rockets and propelled missiles and vehicles.** R. C. Perriton. *Paper VI–3, Second International Congress of Rockets and Satellites, Paris* (1959).

.4 *Refractories*

[*See also* abstract no. 350]

(351) **New graphites beat missile hot-spots.** I. Stambler. *Aviation Age*, **29** (4), 86–8, 90–2 (*April*, 1958). Discusses the advantages of graphite as a structural bearing or seal material in rocket design.
(352) **Stability of ceramics in hydrogen between 4000 deg. and 4500 deg. F.** C. E. May, D. Koneval and G. C. Fryburg. *N.A.S.A. Rept.* 3–5–59*E*, 13 pp. (*March*, 1959). (11 *refs.*)

.5 *Plastics*

(353) **Reinforced plastics for rocket motors and re-entry heat shields.** H. A. Perry, I. Silver, H. C. Anderson and F. A. Mihalow. *Third Symp. on Materials Res. in the U.S. Navy Prepr.* (1959).

4—BIOLOGY AND MEDICINE

.1 *General*

(354) **Interstellar migration and the population problem.** G. Hardin. *J. Heredity*, **50**, 68–70 (*March-April*, 1959). (6 *refs.*)
(355) **The ecospheres of the variable stars.** J. Gadomski. 11*th Internat. Astronaut. Congr.*, 6 pp. (1960). (*In German.*) Calculation of the ecospheres of 406 pulsating variable stars and the conditions on the surfaces of the potential planets of these stars leads to the conclusion that conditions are unsuitable for the origin and development of life.
(356) **Space ecological systems 1960–1975.** E. B. Konecci. 11*th Internat. Astronaut. Congr.*, 15 pp. (1960). In a space cabin the ecological system includes the astronaut(s) and their

closed environment. Existing and proposed subsystems and their relation to the whole are reviewed. Ecological systems cannot be considered as separate entities in a space vehicle system; for a given mission the type of ecological system employed will depend on the propulsion capabilities. Earth-orbital and Martian systems are mentioned as examples.

(357) **Extraterrestrial microbiology**. W. Vishniac. *Aerospace Med.*, **31**, 678–80 (*Aug.*, 1960). An apparatus is proposed and described which, being deposited on Mars, would inoculate a culture tube by drawing in dust and atmospheric particles. Any change in acidity or turbidity would be telemetered to the Earth.

.3 *Zoology*

(358) **The effect of some physical forces on action potentials in guinea pig sciatic nerve**. R. M. Morrell. 11*th Internat. Astronaut. Congr.*, 5 pp. (1960). The effects of positive acceleration, subgravity and vibration on conduction velocity, amplitude, duration and refractoriness of responses of guinea pig sciatic nerves in Ringer's solution were studied, using FM–FM radio telemetry. (11 *refs.*)

(359) **Tin can housing roaches may be hurled into space in fall**. H. Howard. *Amer. Metal Market*, **67** (164), 1–2 (25 *Aug.*, 1960). Beltsville Laboratory of U.S. Dept. of Agriculture's Research Center, University of Maryland, are trying to persuade NASA to include cockroaches in long space flights—these insects can live without food for 3 weeks and have a life rhythm tied to light/dark conditions.

.4 *Anatomy and Physiology*
[*See also* abstract no. 626]

(360) **Human factors**. K. J. Buettner. *Aviation Age*, **28** (9), 78–82, 84–6, 89 (*March*, 1958). Considers the physical and psychological consequences of weightlessness, space-ship cabin conditions, and the hazard from cosmic rays.

(361) **Getting man into space**. W. A. Orr and J. W. Tucker. *Aviation Age*, **28** (9), 30–1, 102–5 (*March*, 1958). An overall view of the problems of manned spaceflight.

(362) **CO_2 disposal, leakproofing, zero gravity: problems for spacecraft air conditioning**. F. H. Green. *Aviation Age*, **29** (5), 174–9 (*May*, 1958).

(363) **Sealed cabin atmosphere problems**. E. R. Archibald and D. G. Simons. *Prepr. World Congress of Aviation Medicine, Louvain*. 10 pp. (*Sept.*, 1958).

(364) **Space biological research tests need instrument improvement**. C. Lewis. *Aviation Wk.*, **69** (19), 55, 57, 59, 61 (10 *Nov.*, 1958).

(365) **Flight experiments about human reactions to accelerations which are followed or preceded by the weightless state**. H. J. von Beckh. *AFMDC TN* 58–15, 50 pp. (*Dec.*, 1958).

(366) **Zero gravity tests show man can adjust to space**. *Aviation Wk.*, **69** (25), 52–3, 55 (22 *Dec.*, 1958).

(367) **Gen. Flickinger views survival in space**. D. Flickinger. *Aviation Wk.*, **69** (25), 43, 46–7, 49, 51 (22 *Dec.*, 1958).

(368) **Research of human performance during zero gravity**. E. L. Brown. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–10, 4 pp. (1959).

(369) **Psycho-physiological centred space-vehicle design**. A. J. Cacioppo. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–13, 6 pp. (1959).

(370) **Environmental requirements for extended occupancy of manned satellites**. S. H. Dole. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–12, 12 pp. (1959).

(371) **Designing for human capabilities under acceleration in satellite operations**. R. C. Kaehler, J. P. Meehan and T. Freedman. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–34, 4 pp. (1959).

(372) **Physiological factors in space flight**. E. B. Konecci. *Paper VIII–1, Second Internat. Congr. of Rockets and Satellites, Paris* (1959.)

(373) **Environmental control systems for manned space vehicles**. R. A. Nau. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–11, 9 pp. (1959). (11 *refs.*)

(374) **Artificial "*g*" fields: perception of the vertical**. J. T. Ray. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–8, 8 pp. (1959).

(375) **The conquest of space, a function of human resistance**. M. de Roisin. *Paper VIII–2, Second Internat. Congr. of Rockets and Satellites, Paris* (1959). (*In French.*)

(376) **Study of the possibilities of survival during the course of a circum-lunar voyage**. F. Violette, H. Boiteau and S. Bernard. *Paper VIII–3, Second Internat. Congr. of Rockets and Satellites, Paris* (1959). (*In French.*)

(377) **Human factors design requirements for manned satellite vehicles—a survey of equipment requirements**. H. L. Wolbers. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–14, 8 pp. (1959). (7 *refs.*)

(378) **Viability surveillance and data collection in biosatellite experiments**. A. W. Hetherington. *Inst. Aeronaut. Sciences Repr.* 59–22, 14 pp. (*Jan.*, 1959).

(379) **Implications of space radiations in manned space flight**. W. H. Langham. *Inst. Aeronaut. Sciences Repr.* 59–52, 18 pp. (*Jan.*, 1959).

(380) **Studies of pilot control during launching and re-entry of space vehicles, utilizing the human centrifuge**. C. H. Woodling and C. C. Clark. *Inst. Aeronaut. Sciences Repr.* 59–39, 19 pp. (*Jan.*, 1959). (4 *refs.*)

(381) **Aeromedical problems in space sciences**. N. L. Barr. *Seminar in Astronautics and Space Sciences, Univ. Rome* (18–29 *May*, 1959).

(382) **Keeping your feet on the ground—in space**. *Astronautics*, **4** (6), 28 (*June*, 1959).

(383) **The Mercury astronauts**. *Astronautics*, **4** (6), 22, 42 (*June*, 1959).

(384) **Protective role of hypothermia against X-rays**. J. M. Radulovic. 11*th. Internat. Astronaut. Congr.*, 7 pp. (1960). Tests on adult white rats demonstrated that hypothermia (reduced body temperature) could protect the organism against the destructive effects of X-rays. This offers the possibility of preserving life during interstellar travel. (50 *refs.*)

(385) **Visceral displacement in black bears subjected to abrupt deceleration**. J. E. Cook and J. D. Mosely. *Aerospace Med.*, **31**, 1–8 (*Jan.*, 1960). Analysis of injuries to 8 animals strapped in various attitudes on a rocket sled and subject to peak decelerations of from 25·0 *g* to 123·6 *g*. (4 *refs.*)

(386) **High altitude protection from pressure-breathing mask with trunk and lower limb counterpressure**. J. Ernsting, I. D. Green, R. E. Nagle and P. R. Wagner. *Aerospace Med.*, **31**, 40–8 (*Jan.*, 1960). Experiments showed that the system does not protect reliably against anoxia during exposure of more than 30 sec. at 56,000 ft. followed by descent to 40,000 ft. at 10,000 ft./min. (4 *refs.*)

(387) **Medical problems in testing high altitude pressure suit**. C. L. Wilson and M. B. Zinn. *Aerospace Med.*, **31**, 49–56 (*Jan.*, 1960). Tests include rapid decompression after denitrogenation, which prevented "the bends" occurring; and effects of windblast at 350 miles/hr., which caused no damage to the suit.

(388) **Bibliography of sensory deprivation, isolation and confinement**. B. B. Weybrew. *Naval Medical Res. Lab., New London, Conn. Memorandum Report No.* 60–1 (*Task No. MR*005.14–2100.03.04; *Subtask No.* 3, *Report No.* 4) (*Jan.*, 1960). 146 references are divided into 9 categories including "Studies of confinement peculiar to spaceflight."

(389) **Cardiovascular functions in the dog rewarmed rapidly and slowly from deep hypothermia**. H. E. D'Amato, S. Kronheim and B. G. Covino. *Amer. J. Physiology*, **198** (2), 333–5 (*Feb.*, 1960). On rapid rewarming (in warm water) from 25° or 20° C. rectal temperature, there was no consistent failure in recovery of normal heart and circulation functions; but failure was observed in some or all of these functions on slow rewarming (in heated sheeting).

(390) **Synergism between effects of hyperventilation, hypoglycemia and positive acceleration**. H. P. Brent, T. M. Carey, T. J. Powell, J. W. Scott, W. J. R. Taylor and W. R. Franks. *Aerospace Med.*, **31**, 101–15 (*Feb.*, 1960). In 18 subjects, untoward symptoms were worse and more frequent (*a*) when hyperventilation and acceleration (3·4 *g*) acted together than when applied separately; and (*b*) 3 hr. after glucose feeding than 1 hr. after. (18 *refs.*)

(391) **A system for monitoring the ECG [electrocardiograph] under dynamic conditions**. W. J. Carbery, W. E. Tolles and A. H. Freiman. *Aerospace Med.*, **31**, 131–7 (*Feb.*, 1960). Describes a monitoring system suitable for studying heart action "during aircraft and satellite flights."

(392) **Prolonged exposure in the Navy full pressure suit at "space equivalent" altitudes**. A. L. Hall and R. J. Martin. *Aerospace Med.*, **31**, 116–22 (*Feb.*, 1960). One 36-year-old subject spent 76½ hr. in a pressure suit breathing 100% oxygen at 35,000 ft. pressure equivalent (equal to oxygen partial pressure

at sea level). Main troubles were irritation of eyes due to dryness of the oxygen, inflammation of bony prominences, skin rash, and some cramp in legs after 67 hr. (13 *refs.*)

(393) **Effect of continuous human exposure to oxygen tension of 418 mm. Hg for 168 hours.** E. L. Michel, R. W. Langevin and C. F. Gell. *Aerospace Med.*, **31**, 138–44 (*Feb.*, 1960). Six subjects were confined for 7 days in air with 80% oxygen at a pressure equivalent of 10,000 ft. (equivalent to 55% oxygen at sea level). All complained of discomfort below the sternum (breastbone); two suffered diminished vital capacity (of lungs), one of whom developed some atelectasis (collapse of smaller air cavities). (17 *refs.*)

(394) **Roentgenographic study of human subjects during transverse acceleration.** E. J. Hershgold. *Aerospace Med.*, **31**, 213–9 (*March*, 1960). Displacements of organs in chest and abdomen were measured. It is recommended that, during forward acceleration (as when lying on the back during take-off), a device should rotate the torso so as to allow each lung to inflate alternately, while holding the head still. (4 *refs.*)

(395) **Physiological effects of cabin pressure failure in high altitude passenger aircraft.** C. A. Bryan and W. G. Leach. *Aerospace Med.*, **31**, 267–75 (*April*, 1960). Eight fit subjects were decompressed from 8000 to 40,000 ft. equivalent pressure in 2·5 sec., and breathed oxygen from commercial passenger masks. Average time of useful consciousness, 18 sec. Unconsciousness always occurred "with startling suddenness." (7 *refs.*)

(396) **The maintenance of thermal comfort in a full pressure suit at simulated altitude.** L. J. SantaMaria, S. J. Klein and H. R. Greider. *Aerospace Med.*, **31**, 288–95 (*April*, 1960). Three subjects were each exposed, in full pressure suits at 18,000 ft. simulated altitude, to different combinations of ambient air at 125° or 150° F. (51·7° or 65·6° C.) with ventilating air at 90° or 60° F. (32·2° or 15·6° C.) for 2 hr. All remained comfortable, but for longer periods loss of body fluid would exceed a safe level.

(397) **Oxygen sources for spaceflights.** R. M. Bovard. *Aerospace Med.*, **31**, 407–12 (*May*, 1960). Two new sources were tested and gave satisfaction, especially when combined: potassium superoxide releases oxygen on reacting with exhaled moisture and carbon dioxide; sodium chlorate candles start the reaction and also generate oxygen themselves, and could provide an emergency source of oxygen "surge." (6 *refs.*)

(398) **Functional relationships between semicircular canals and otolith organs.** R. F. Gray. *Aerospace Med.*, **31**, 413–8 (*May*, 1960). It is argued that these two sets of organs are not confined to sensing, respectively, angular and linear accelerations, but react on each other. This is deduced especially from illusions experienced on a centrifuge. (7 *refs.*)

(399) **A review of available information on the acoustical and vibration aspects of manned spaceflight.** H. L. Jacobs. *Aerospace Med.*, **31**, 468–77 (*June*, 1960). Conclusions from 11 published papers are that "the noise environment should not create a barrier to manned space travel," and "vibration, as limited by the structural requirements of current space vehicle design, is within human tolerance." (11 *refs.*)

(400) **Basic research problems in space medicine: a review.** R. T. Clark, H. G. Clamann, B. Balke, P. C. Tang, J. D. Fulton, A. Graybiel and J. Vogel. *Aerospace Med.*, **31**, 553–77 (*July*, 1960). Principal subjects treated are weightlessness, terrestrial organisms in simulated Martian environment, and tests for selection of space pilots.

(401) **Observations on heart rate and cardiodynamics during weightlessness.** G. E. Burch and S. J. Gerathewohl. *Aerospace Med.*, **31**, 661–9 (*Aug.*, 1960). A review of five series of experiments shows that the stresses are "well within the range of tolerance of the human and animal organism." A common feature in the early stage of weightlessness is "prolonged and fluctuating tachycardia" (increased heart rate). (18 *refs.*)

(402) **Eye hazards and protection in space.** H. Strughold and O. L. Ritter. *Aerospace Med.*, **31**, 670–3 (*Aug.*, 1960). A permanent burn on the retina could be caused by looking directly at the Sun in space, outside the Earth's atmosphere, for 10 sec. or less, the authors estimate. The same figure applies in the neighbourhood of any other planet, the only difference being in the size of the burn. (14 *refs.*)

.7 *Psychology*

(403) **Studies in Human Isolation.** S. J. Freedman and M. Greenblatt. *Massachusetts Mental Health Center, Boston, Mass.* (*Contract AF* 33 (616)–5663)*; issued by Wright Air Development Center. Aerospace Medical Lab., Wright-Patterson Air Force Base, Ohio. WADC Technical Report No.* 59–266 (*Project No.* 7220, *Task No.* 71741) (*Sept.*, 1959). Thirty subjects were isolated for 8 hr. with or without sensory deprivation or with meaningless stimuli only. The authors propose that symptoms are due to "the organism's continuous automatic search for order in a non-ordered perceptual environment."

(404) **The effect of visual stimulation on hallucinations and other mental experiences during sensory deprivation.** J. M. Davis, W. F. McCourt, and P. Solomon. *Amer. J. Psychiatry*, **116** (10), 889–92 (*April*, 1960). Ten subjects were, during periods of up to 10½ hr., deprived of sensory stimulation except for meaningless random light flashes and the showing of coloured cards. Mental aberations resulted, showing that symptoms of sensory deprivation are due to absence of meaningful stimulation rather than absence of sensory stimulation as such.

(405) **Performance and habitability aspects of extended confinement in sealed cabins.** T. D. Hanna and J. Gaito. *Aerospace Med.*, **31**, 399–406 (*May*, 1960). Six naval subjects were confined for 7 days in a closed chamber, divided into work and leisure rooms, with a total volume of 75 ft.^{3} per man, spending 10 hr. a day on tasks. No deterioration of intellectual or psychomotor functions was shown. Morale was highest around the beginning and end but decreased in the middle of the period. The simpler tasks were found too boring.

(406) **Airborne GSR (galvanic skin response) studies.** G. J. D. Schock. *Aerospace Med.*, **31**, 543–6 (*July*, 1960). Three subjects were exposed to 30–40 sec. of weightlessness in a jet aircraft. GSR fell before onset of weightlessness, indicating emotional disturbance, presumably anxiety, but rose again during weightlessness.

5—AVIATION AND AERODYNAMICS

.2 *Aerodynamics*

[*See also* abstract no. 691]

(407) **Aerophysical problems of flight at extreme altitudes and speeds.** G. N. Patterson. *Canad. Aeronaut. J.*, **4**, 3–10, 39–47, 79–85 (1958). (98 *refs.*)

(408) **An approximate analytical method for studying entry into planetary atmospheres.** D. R. Chapman. *N.A.C.A. Tech. Note* 4276, 101 pp. (*May*, 1958).

(409) **Analysis of the aerodynamic heating for a re-entrant space vehicle.** M. J. Brunner. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–5, 7 pp. (1959). (9 *refs.*)

(410) **Hyperballistic techniques in aerophysical research.** G. V. Bull. *Paper III–4, Second Internat. Congr. of Rockets and Satellites, Paris* (1959).

(411) **Use of drag modulation to reduce deceleration loads during atmospheric entry.** R. L. Phillips and C. B. Cohen. *ARS J.*, **29** (6), 414–22 (*June*, 1959). (6 *refs.*)

(412) **Magnetohydrodynamic effects in aerodynamic flows.** W. R. Sears. *ARS J.*, **29** (6), 397–406 (*June*, 1959). (50 *refs.*)

.3 *Rocket-Propelled Aircraft*

(413) **General variational theory of the flight paths of rocket powered aircraft, missiles and satellite carriers.** A. Miele. *Purdue Univ. School Aero. Engng. Rept. A*–58–2, (*AFOSR–TN*–58–246; *ASTIA AD* 154148), 57 pp. (*Jan.*, 1958).

(414) **X-15 design reflects hypersonic mission.** I. Stone. *Aviation Wk.*, **69** (17), 88–9, 91, 93, 97–8 (27 *Oct.*, 1958).

(415) **The X-15: America's manned missile.** B. J. Haimes. *New Scientist*, **4**, 1526–8 (18 *Dec.*, 1958).

.4 *Test Facilities*

[*See also* abstracts nos. 684–5]

(416) **Electric arc gas heaters for re-entry simulation and space propulsion.** J. R. Brogan. *ARS Tech. Paper* 724–58, 28 pp. (1958). (7 *refs.*)

(417) **Equipment for simulation of kinetic heating.** G. Maas. *Paper V–2, Second Internat. Congr. of Rockets and Satellites, Paris* (1959). (*In French.*)

(418) **Hypersonic shock tunnel.** H. T. Nagamatsu, R. E. Geiger and R. E. Sheer. *ARS J.*, **29** (5), 332–40 (*May*, 1959). (31 *refs.*)

6—ASTRONAUTICS

.1 *General*

[*See also* abstracts nos. 409, 545, 557, 567–9, 572, 616, 621, 624–5, 646, 651 and 659]

(419) **Space research.** *Science in Parliament* (82), 14–16. Report of question and debate in Parliament, including announcement of limited U.K. programme.

(420) **Space research.** *Science in Parliament* (83), 22–3. Report of questions in Parliament concerning U.K. participation in Canadian programme.

(421) **Navy details needs for space mission.** C. Brownlow. *Aviation Wk.*, **68** (12), 37–8, 41 (24 *March*, 1958).

(422) **Flight testing in the space age.** A. W. Blackburn. *Canad. Aeronaut. J.*, **4**, 125–30 (*April*, 1958). (6 *refs.*)

(423) **On the mechanisms of meteoric ablation.** S.-I. Cheng. *Princeton Univ., Dept. Aeronaut. Engng. Rept.* 427 (*AFOSR–TN–58–649; ASTIA AD* 162181), 21 pp. (*April*, 1958).

(424) **U.S.A.F. Directorate backs space study.** I. Stone. *Aviation Wk.*, **68** (14), 50–3, 55, 58, 61–2 (7 *April*, 1958).

(425) **President details NACA space mission.** *Aviation Wk.*, **68** (15), 51, 53 (14 *April*, 1958). Text of Eisenhower's address to Congress recommending the formation of N.A.S.A.

(426) **Astronautics—science of space exploration; an introduction and summary of progress.** G. D. Watson. *Canad. Aeronaut. J.*, **4**, 185–93 (*June*, 1958). Ranges from Chinese rockets to planetary colonization. (33 *refs.*)

(427) **Astronautics in Amsterdam.** K. W. Gatland. *Flight*, **74**, 434–5 (12 *Aug.*, 1958). Report of proceedings at the 9th I.A.F. Congress.

(428) **Spaceflight becomes a reality.** *Interavia*, **13** (10), 1096–8 (*Oct.*, 1958). Account of the 9th I.A.F. Congress in Amsterdam.

(429) **A.R.P.A. official gives details on man-in-space program.** E. Clark. *Aviation Wk.*, **69** (20), 26–7 (17 *Nov.*, 1958).

(430) **Simulation of thermal environment in space.** J. B. Cladis. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–26, 4 pp. (1959).

(431) **On the economy and techniques of large booster recovery.** H. H. Koelle. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–1, 7 pp. (1959). (5 *refs.*)

(432) **Tomorrow the Moon.** A. and R. B. Marcus. $3.50, approx. 150 pp., *Prentice-Hall, Englewood, N.Y., U.S.A.* (1959). Popular.

(433) **Economic considerations of spaceflight ground-support requirements.** M. A. Margolis and F. S. Pardee. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–15, 8 pp. (1959).

(434) **The scientific and technical significance of space rocket experiments.** E. Nagy. *Magyar Tudomány*, (3), 141–9 (1959). (*In Hungarian.*)

(435) **Numerical methods useful for the solution of theoretical problems in astronautics.** B. Renard. *Paper II–7, Second Internat. Congr. of Rockets and Satellites, Paris* (1959). (*In French.*)

(436) **Astronautical departure and return.** S. Travers. *Paper V–1, Second Internat. Congr. of Rockets and Satellites, Paris* (1959). (*In French.*)

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(438) **The balloon-borne capsule as a spaceflight trainer.** E. E. Beson. *Inst. Aeronaut. Sciences Repr.* 59–46, 19 pp. (*Jan.*, 1959).

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(440) **Space trainer simulates hypersonic orbit.** C. Lewis. *Aviation Wk.*, **70** (16), 56–7, 59–61, 63 (20 *April*, 1959). Trainer for pilots of re-entry vehicles.

(441) **Designing small space payloads.** R. G. McCarty. *Astronautics*, **4** (5), 24–5, 96–7 (*May*, 1959).

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(443) **Present and future accomplishments and trends in space activities.** N. Rothrock. *Seminar in Astronautics and Space Sciences, Univ. of Rome* (18–29 *May*, 1959).

(444) **Solid rockets in space: where do we go?** P. Means. *Missiles and Rockets*, **5** (21), 20–2 (25 *May*, 1959).

(445) **Second International Congress of Rockets and Satellites.** *Fusées*, (12), 40–61 (*June*, 1959). (*In French and English.*) Abstracts of papers.

(446) **Papers presented at the IXth International Astronautical Congress.** A. Eula. *Missili*, **1** (3), 45–50 (*June*, 1959). (*In Italian.*) Extended abstracts of a few of the papers.

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(449) **Optimum staging techniques.** L. Weisbord. *ARS J.*, **29**, 445–6 (*June*, 1959). (7 *refs.*)

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.2 *Artificial Satellites*

[*See also* abstracts nos. 310–13, 321, 327, 328, 330, 332–4, 337, 339–40, 377–8, 383, 413, 437, 450, 486–7, 489–91, 493–504, 507, 509, 512, 516, 518–20, 522, 525–6, 528, 534, 536, 538–40, 555, 620, 664, 704, 706–7, 710 and 712–4]

(451) **Experiences in the photographic observation of artificial Earth satellites with the help of Maxutov meniscus telescopes.** D. A. Roskovskii. *Astronomicheskii Zhurnal*, **35**, 479–85 (1958). (*In Russian.*) (5 *refs.*)

(452) **Vanguard's success forestalls its critics.** J. S. Butz. *Aviation Wk.*, **68** (12), 21–3 (24 *March*, 1958).

(453) **Convair plans four-man space station.** E. Clark. *Aviation Wk.*, **68** (17), 26–8 (28 *April*, 1958).

(454) **Instruments in *Sputnik III*.** R. L. Boyd. *New Scientist*, **4**, 14–5 (22 *May*, 1958).

(455) **The future of man-made Earth satellites.** A. C. Lovell. *New Scientist*, **4**, 12–3 (22 *May*, 1958). A call for a British space-exploration programme.

(456) **Scientist compares U.S.-Red satellites.** S. B. Kramer. *Aviation Wk.*, **68** (21), 50–1, 53, 55, 59 (26 *May*, 1958). Includes tabular comparison of data on Vanguard, *Explorer I, Explorer III, Sputnik I, Sputnik II, Sputnik III*, satellites and launching rockets.

(457) **Work on Pied Piper accelerated; satellite has clamshell nose cone.** *Aviation Wk.*, **68** (25), 18–9 (23 *June*, 1958).

(458) **U.S. designs infra-red scanner satellite.** J. A. Fusca. *Aviation Wk.*, **69** (6), 82–4, 87 (18 *Aug.*, 1958). Proposal for cloud-surveying weather satellite.

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(460) **Problems associated with the assembly of a multi-unit satellite in orbit.** W. H. Clohessy and R. S. Wiltshire. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–25, 9 pp. (1959).

(461) **Economics of satellite supply vehicles.** R. Cornog. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–33, 13 pp. (1959). (8 *refs.*)

(462) **Some fundamental problems associated with injecting, orbiting and recovering a man from orbit.** R. C. Hakes. *Inst. Aeronaut. Sciences Repr.* 59–80, 10 pp. (1959).

(463) **The nuclear submarine as a manned satellite laboratory.** A. E. Hickey. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–9, 4 pp. (1959).

(464) **The design characteristics of inflatable aluminized-plastic spherical Earth satellites with respect to ultraviolet, visible, infrared and radar radiation.** G. P. Wood and A. F. Carter. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–38, 8 pp. (1959). (11 *refs.*)

(465) **The problem of escape from satellite vehicles.** C. V. Carter and W. W. Huff. *Inst. Aeronaut. Sciences Repr.* 59–41, 28 pp. (*Jan.*, 1959). (7 *refs.*)

(466) **Free flight test of a technique for inflating an N.A.S.A. 12 ft. diameter sphere at high altitudes.** A. B. Kehlet and H. G. Patterson. *N.A.S.A. Memo.* 2–5–59*L*, 18 pp. (*Jan.*, 1959). (3 *refs.*)

(467) **Score—first communications satellite.** M. I. Davis and G. N. Krassner. *Astronautics*, **4** (5), 37–9, 88, 91–2, 94–5 (*May*, 1959).

(468) **Communications satellites: a largely neglected force for peace.** H. Gettings. *Missiles and Rockets*, **5** (19), 38–40 (11 *May*, 1959).

(469) **N.A.S.A.'s Project Mercury range to cost $12 million plus.** P. Means and H. Gettings. *Missiles and Rockets*, **5** (20), 26–7 (18 *May*, 1959).

(470) **Progress on Project Mercury.** *Astronautics*, **4** (6), 30–1 (*June*, 1959).

(471) **Space transport by in-transit rendezvous techniques.** C. E. Kaempen. 11*th Internat. Astronaut. Congr.*, 14 pp. (1960). These techniques involve trajectory operations conducted by two or more individually launched space vehicles which rendezvous in transit for assembly into a single unit which then proceeds to its terminal objective. It is claimed to provide a means whereby the system reliability and development expense associated with a particular Earth-launch system can be fully exploited to provide the mission capability of a single system of considerably greater size. Examples are given for lunar and Mars missions.

(472) ***Pioneer V* and *Explorer VI*, systems engineered space probes.** G. E. Mueller. 11*th Internat. Astronaut. Congr.*, 16 pp. (1960). Detailed description of the *Pioneer V* space probe placed in a heliocentric orbit approaching the orbit of Venus; it is the end result of a series of space probes (notably *Explorer VI* satellite) which have served to perfect its components, and the systems approach is emphasized. Some of the results obtained with *Pioneer V* are considered.

(473) **The post-launch performance of the *Tiros I* satellite.** S. Sternberg. 11*th Internat. Astronaut. Congr.*, 11 pp. (1960). *Tiros I* is the first of the experimental TV-equipped meteorological satellites. It contains two TV cameras (one wide-angle and one high-resolution, narrow-angle) for photographing cloud cover from an altitude of 400 miles, and their output is transmitted to Earth-based stations. The performance in orbit is still being evaluated, but it is evident that the thermal design of the satellite, the camera coverage and resolution, power supply, and radio communication have proved successful. Temporary trouble was experienced with the function-controlling clock of one camera system, and the attitude of the satellite's spin axis has changed at a greater rate than expected. The meteorological results have been extremely satisfactory, and both known and new cloud and weather phenomena have been observed.

(474) **Charts to determine the visibility of artificial Earth satellites.** P. D. Jose and M. Duffy. *Air Force Missile Devel. Center TR*–59–10 (*April*, 1959).

.3 *Lunar and Planetary Probes*

[*See also* abstracts nos. 319–21, 340, 376, 505–6, 508, 515, 529 and 537]

(475) **Problems associated with power requirements for a Mars mission.** J. H. Fisher and W. R. Menetry. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–18, 12 pp. (1958).

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(477) **The penetration of planetary atmospheres.** C. Gazley. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–27, 11 pp. (1959). (8 *refs.*)

.4 *Spaceships*

[*See also* abstracts nos. 345, 356, 362–3 and 369–70]

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(479) **Spacecraft structural factors studied.** M. Yaffee. *Aviation Wk.*, **69** (23), 55, 57, 59–60 (8 *Dec.*, 1958).

(480) **Effectiveness of radiation as a structural cooling technique for hypersonic vehicles.** R. A. Anderson and W. A. Brooks. *Inst. Aeronaut. Sciences Repr.* 59–65, 27 pp. (1959).

(481) **Some radiator design criteria for space vehicles.** J. P. Callinan and W. P. Berggren. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–29, 17 pp. (1959).

(482) **Man-machine integration in space vehicles.** G. W. Hoover. *Inst. Aeronaut. Sciences Repr.* 59–51, 13 pp. (*Jan.*, 1959).

(483) **Thermostatic temperature control of satellites and space vehicles.** R. A. Hanel. *ARS J.*, **29** (5), 358–61 (*May*, 1959). (7 *refs.*)

(484) **Structural and thermal problems in space vehicles.** L. Broglio. *Seminar in Astronautics and Space Sciences, Univ. Rome* (18–29 *May*, 1959). (*In Italian.*)

(485) **Selected areas of structural research in rocket vehicles.** M. L. Williams, G. Gerard and G. A. Hoffman. 11*th Internat. Astronaut. Congr.*, 21 pp. (1960). Reviews progress in three areas demonstrating the design interaction between structures and materials: the application of viscoelastic analysis to solid propellent grains, the design of shell structures in homogeneous materials, and the effect of filamentary materials (particularly metallic and non-metallic whiskers) on pressure vessel design. In the last section it is concluded that filamentary materials may enable the mass of pressure vessels to be reduced to $\frac{1}{5}$–$\frac{1}{6}$ of their present values; they are already competitive and show some slight advantages over metal vessels. (29 *refs.*)

.6 *Orbits*

(486) **Simplified satellite prediction from modified orbital elements.** $1.00, *Publications Off., National Academy of Sciences, Washington 25, D.C.*

(487) **On satellite orbits. Parts I and II.** H. Knothe and R. Anderson. (I). [*U.S.*] *Air Force Missile Devel. Center TR*–11 (*April*, 1959). (II). [*U.S.*] *Air Force Missile Devel. Center TR*–59–19. *ASTIA Document No. AD* 215112 (*May*, 1959).

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(489) **Processed observational data for satellites 1957 alpha and 1957 beta.** R. M. Adams, N. McCumber and M. Brinkman. *Smithsonian Contributions Astrophysics*, **2**, 287–337 (1958).

(490) **Glossary of astronomical terms for the description of satellite orbits.** J. Ashbrook, G. F. Schilling and T. E. Sterne. *Smithsonian Contributions Astrophysics*, **2**, 211–17 (1958).

(491) **Visual observations of satellite 1957 α1 made by Moonwatch stations.** L. Campbell and J. A. Hynek. *Smithsonian Contributions Astrophysics*, **2**, 245–74 (1958).

(492) **Relativistic treatment of rocket propulsion and maximum end velocity of a rocket taking in consideration nuclear data.** T. Foelsche. *Atompraxis*, **4**, 431–5 (1958). (*In German.*) (6 *refs.*)

(493) **Basic orbital data for satellite 1957 β1.** L. G. Jacchia. *Smithsonian Contributions Astrophysics*, **2**, 285–6 (1958).

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(495) **Influence of air drag on the motion of a satellite.** H. Molitz. *Wehrtechnische Monatshefte*, **55**, 593–607 (1958). (*In German.*) (4 *refs.*)

(496) **Study on the movement of artificial satellites in a resistant medium.** M. M. Nitã. *Stud. Cerc. Mec. Apl.*, **9**, 337–58 (1958). (*In Rumanian.*) (15 *refs.*)

(497) **Additional orbit information for USSR satellites 1957 α1 and β1.** J. S. Rinehart and G. F. Schilling. *Smithsonian Contributions Astrophysics*, **2**, 199–205 (1958).

(498) **Soviet orbit information for satellites 1957 α2 and β1.** G. F. Schilling. *Smithsonian Contributions Astrophysics*, **2**, 281–4 (1958).

(499) **Soviet orbit predictions and orbital information for satellites 1957 α1, α2 and beta.** G. F. Schilling and E. S. Fergusson. *Smithsonian Contributions Astrophysics*, **2**, 219–44 (1958).

(500) **Preliminary orbit information for USSR satellites 1957 α1 and β1.** G. F. Schilling and T. E. Sterne. *Smithsonian Contributions Astrophysics*, **2**, 191–8 (1958).

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(502) **A short program for satellite orbit prediction.** I. Harris and R. Jastrow. *U.S. Naval Res. Lab. Progr. Rept.* 1–8 (*PB* 131635) (*Feb.*, 1958).

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(506) **On the dynamics of Moon voyages.** W. A. Jegorow. *Naturwissenschaften Rundschau*, **11**, 426–9 (*Nov.*, 1958). (*In German.*)

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(508) **On the trajectories of lunar projectiles.** T. P. Angelitch. *Vasiona*, **7**, 5–7 (1959). (*In Serbo-Croat.*) (4 *refs.*)

(509) **Dynamic problems associated with satellite orbit control.** B. W. Augenstein. *Amer. Soc. Mech. Engrs. Prepr.* 59–*AV*–4, 8 pp. (1959). (13 *refs.*)

(510) **Effect of rapid deceleration on the dynamic stability of a re-entry body.** E. V. Laitone. *Paper III–5, Second Internat. Congr. of Rockets and Satellites, Paris* (1959).

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(514) **Some problems of space navigation.** (**Aero-space engineering.**) R. E. Roberson. *Paper III–2, Second Internat. Congr. of Rockets and Satellites, Paris* (1959).

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(519) ***Discoverer II* orbital attitude controlled.** R. Sweeney. *Aviation Wk.*, **70** (16), 26–7 (20 *April*, 1959).

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(527) **On the use of side-jets as control devices.** H. P. Liepman. *ARS J.*, **29** (6), 453–4 (*June*, 1959). (3 *refs.*)

(528) **An optimum transfer path from an elliptical orbit to a higher energy circular orbit.** H. Munick. *ARS J.*, **29** (6), 449–51 (*June*, 1959). (2 *refs.*)

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(533) **Trajectories for direct vehicle transfer from Moon to Earth.** R. J. Gunkel and R. H. Shutte. 11*th Internat. Astronaut. Congr.*, 11 pp. (1960). An investigation of possible direct ballistic transfer of transport vehicles from the Moon to landing areas on Earth, with particular attention to the sensitivity of initial condition errors. The importance of such parameters as location of launch site, location of landing area, and departure velocity are discussed. The results indicate that very little control of the velocity vector in magnitude of direction will be required for the early attempts of return flight where the objective is the landing of an instrumented capsule anywhere on the Earth's surface. In later manned return flights, where the objective will be to land on a particular area of the Earth, guidance systems of a high degree of accuracy will be required during the powered phase. The most desirable location of the launch site is in the vicinity of the mean central point of the visible disc. (8 *refs.*)

(534) **Guidance and control of "24-hour" communication satellites.** H. K. Karrenberg and R. E. Roberson. 11*th Internat. Astronaut. Congr.*, 8 pp. (1960). Functional requirements for guidance and control of satellites in 24-hour equatorial orbits, which appear to remain fixed above a point on the Earth. Guidance during ascent to nominal orbit, correction of errors at end of final injection, orbit perturbations, correction of orbit elements, compensation of perturbing forces, attitude requirements and control. (9 *refs.*)

(535) **Some orbital elements useful in space trajectory calculations.** W. Kizner. 11*th Internat. Astronaut. Congr.*, 27 pp. (1960). Two sets of orbital elements are used. The **B** set is used when in the region of influence of the target planet, when the motion is hyperbolic, or when there is the possibility that the motion will become rectilinear. It makes use of **B**, the impact parameter vector, which is in the orbital plane directed perpendicularly to the incoming asymptote of the osculating hyperbola. This set provides a convenient description of miss distance and furnishes simple relationships for many complex geometrical problems in lunar and interplanetary flight. The second set (called the **w** set) is used when the orbital plane is well defined and there is a large eccentricity.

(536) **Development of dynamical study of an artificial satellite.** J. Kovalevsky. 11*th Internat. Astronaut. Congr.*, 6 pp. (1960). (*In French.*) Origin and nature of perturbations in artificial satellite motion. Most of the short-period disturbances of the osculating elements keep the same form over a long period of

time but move along the mean orbit with a period equal to that of the long-period terms with the same cause, thus introducing systematic distortions in the evaluation of real long-period terms. If the observations are performed in such a way that osculating elements can be computed for each observation, short-period terms should be detectable.

(537) **Application of the Jacobi integral of celestial mechanics to the terminal guidance of space probes.** P. Lanzano. 11*th Internat. Astronaut. Congr.*, 11 pp. (1960). The terminal guidance of a lunar probe meant to reach the Moon's surface is considered. The Jacobi integral, representing a relationship between the probe's velocity and position in terms of a constant of motion, determines a set of zero-velocity surfaces which constitute certain barriers for the motion of the probe. The critical Jacobi region around the Moon is defined as the largest, closed, zero-velocity surface surrounding the Moon; the boundary of the region is expressed analytically by means of an infinite series and the maximum orbital velocity that the probe should not exceed in order to prevent its escape from the lunar field is derived. Some numerical results are given. Collision trajectories and initial conditions for impact are also considered. (14 *refs.*)

(538) **About cosmic dust as decelerating factor and a general law for satellite orbits.** A. Lundbak. 11*th Internat. Astronaut. Congr.*, 11 pp. (1960). Changes in the nodal periods of the satellites *Explorer I, Vanguard I, Sputnik III* and *Explorer IV* have been analysed. After eliminating the gradual increase in rate of change that occurs towards the end of the lifetime of a satellite, the effects of latitude, day/night alternation, the Southern hemisphere, charged particles and cosmic dust are considered. Cosmic dust particles are distinguished from ordinary meteorites, and their possible connections with zodiacal light, climate and other phenomena are discussed. (27 *refs.*)

(539) **The stability of the rotation of a cylindrical satellite.** P. Notni and H. Oleak. 11*th Internat. Astronaut. Congr.*, 7 pp. (1960). (*In German.*) Formulae for the torque exerted by the Earth's gravitational field and air resistance on a cylinder are discussed. The precession of the axis of rotation will be less than 0·1 degree per day if (*i*) the three main moments of inertia are nearly equal, (*ii*) the centroid of the cylinder is nearly coincident with its geometrical centre, and (*iii*) the bases of the cylinder are closed.

7—PROPULSION

.1 *General*

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(541) **Performance analysis of plug nozzles for turbojet and rocket exhausts.** W. H. Krase. *Amer. Soc. Mech. Engrs. Prepr.* 59–*GTP*–9, 8 pp. (1959). (7 *refs.*)

(542) **What is specific impulse worth?** E. R. Hinz. *Inst. Aeronaut. Sciences Repr.* 59–23, 25 pp. (*Jan.*, 1959).

(543) **Energy source and propellents.** A. M. Rothrock. *Seminar in Astronautics and Space Sciences, Univ. Rome* (18–29 *May*, 1959).

(544) **The power plant and mission.** A. M. Rothrock. *Seminar in Astronautics and Space Sciences, Univ. Rome* (18–29 *May*, 1959).

(545) **Typical propulsion systems for spaceflight.** R. B. Dillaway. *Fusées*, (12), 27–39 (*June*, 1959). (22 *refs.*)

(546) **Present and future propulsion systems—a survey.** S. K. Hoffman. 11*th Internat. Astronaut. Congr.*, 13 pp. (1960). Reviews the current status of chemical, nuclear and electric propulsion systems. Particular reference is made to the Rocketdyne H–1 and F–1 engines (for Saturn and Nova boosters respectively), and the Rocketdyne Quickmix process for preparing solid propellents.

.2 *Ram-Jets and Air-Breathing Engines*

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.3 *Chemical Rockets*

GENERAL

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.33 PROPELLENTS

[*See also* abstracts nos. 323, 543, 575–8, 581 and 590]

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.5 *Ion Rockets*

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(634) **Electrostatic propulsion design. Principles and problems.** J. M. Sellen, H. Shelton and D. B. Langmuir. *11th Internat. Astronaut. Congr.*, 9 pp. (1960). Quantitative limits for certain design parameters of alkali metal ion rockets are derived. The ion exit orifices and acceleration distances of practical devices must be at the most a few millimetres in size, but the total emitting area must be measured in thousands of square millimetres. Erosion life and charge neutralization are discussed. Injection of electron into broad "stalled" ion beams failed to neutralize the ion space charge; in experiments in which neutralization was achieved it is attributed to gas effects. (19 *refs.*)
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.6 *Miscellaneous*

[*See also* abstracts nos. 416 and 447]

(636) **On the mechanics of photon jet propulsion.** E. Sänger. *Forschungsinstitut für Physik der Strahlantriebe Mitt.* 5, 92 pp. (*Jan.*, 1956). (*In German.*)
(637) **On the radiation physics of photon jet propulsion and radiation weapons.** E. Sänger. *Forschungsinstitut für Physik der Strahlantriebe Mitt.* 10, 173 pp. (*June*, 1957). (*In German.*)
(638) **A description of a propulsive device which employs a magnetic field as the driving force.** R. M. Patrick. *AVCO Manufacturing Corp., AVCO Res. Lab. Rept.* 28, 8 pp. (*May*, 1958).
(639) **Basic factors complicate plasma work.** J. S. Butz. *Aviation Wk.*, **68** (22), 36–9 (2 *June*, 1958). An article on the fundamentals of the subject.
(640) **Giannini plasmadyne studies plasma jet applications.** I. Stone. *Aviation Wk.*, **69** (15), 48–9, 51, 53, 55, 59, 61, 63, 65 (13 *Oct.*, 1958).
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(642) **Factors influencing the application of unconventional rocket engine systems.** G. S. Gill and L. Kusak. *Soc. Automotive Engrs., Paper* 54S, *Nat. Aeronautic Mtg.* (31 *March*–3 *April*, 1959).

(643) **Electric propulsion—measurements with a small thrust plasma generator.** B. Gorowitz and B. W. Harned. *Soc. Automotive Engrs., Paper* 63T, *Nat. Aeronautic Mtg.* (31 *March*–3 *April*, 1959).

(644) **Propulsion by accelerated plasma.** L. Gérardin. *Fusées*, (12), 15–25 (*June*, 1959). (*In French.*) (16 *refs.*)

(645) **Some considerations on the magnetofluiddynamics of jets.** L. G. Napolitano and A. Pozzi. *Missili*, **1** (3), 17–19 (*June*, 1959). (*In Italian.*)

(646) **Heliodyne: a solar-powered interplanetary vehicle.** E. T. Benedikt, R. W. Haliburton and C. C. Kelber. 11*th Internat. Astronaut. Congr.*, 12 pp. (1960). A concept for a hydrogen-propelled space probe whose propulsive energy is derived directly from the Sun. The preliminary design of the Heliodyne vehicle includes a 3-m. diameter spherical liquid hydrogen tank, uninsulated but shadowed by a lightweight meteor bumper, three 90° right circular conical mirrors, a 70-kg. payload, and Sun-seeking equipment. At the focal line of each mirror is a 1-m. length of capillary system in the annulus between a quartz tube (1 cm. i.d.) and a graphite rod (1 cm. o.d.) with 120 grooves (0·5 mm. depth). Hydrogen vapour is heated in this system and passes to a convergent-divergent exhaust nozzle with throat and exit diameters of 3 mm. and 5 cm. respectively. Thermodynamic, heat transfer and optical problems have been considered. At 1 A.U. from the Sun, the maximum value of the specific impulse is estimated to be 710 sec. and the maximum thrust 10^6 dynes. Automatic attitude stability in the radial thrust mode of operation in any orbit trajectory during acceleration has been proven analytically. Typical orbit trajectories and mission applications are discussed.

(647) **A high efficiency plasma motor.** W. H. Bostick and H. Byfield. 11*th Internat. Astronaut. Congr.*, 5 pp. (1960). A pulsed coaxial crater gun generating a plasma from the end of a small-diameter metallic wire is described; it is capable of converting 32% of the energy in a stored capacitor into kinetic energy of the plasma. Its efficiency is constant down to low energy inputs and it has been operated successfully over energy inputs of 3–100 joules per pulse. Specific impulses are about 2000 sec. Measurements of the speed and shape of the plasma have been obtained with a Kerr cell; the plasma speed has also been measured with a calendulum (combined ballistic pendulum and calorimeter) and with a velocity profile measuring instrument.

(648) **A working arc jet rocket engine.** R. R. John, J. F. Connors and A. Mironer. 11*th Internat. Astronaut. Congr.*, 14 pp. (1960). Presents experimental results obtained with a 30 kW. plasma jet rocket engine developed by AVCO Corp. for space propulsion. In this, the simplest of the proposed electric propulsive devices, a working fluid (hydrogen or helium) undergoes Joule heating as it passes through an arc discharge and is then expanded through a conventional nozzle. A thoriated tungsten cathode of special geometry is used in conjunction with a water-cooled copper anode. The electric arc is initiated with a high-frequency spark and caused to rotate about the central cathode to protect the chamber walls. The engine has been operated continuously for periods of 50 hr., and the thrust level is 0·5–1·0 lb., the specific impulse 750–1500 sec., the power level 25–35 kW., and the efficiency 25–75%. A preliminary mission analysis is given and outstanding problems are discussed. (12 *refs.*)

(649) **Internal ballistics of the photon rocket.** W. Peschka. 11*th Internat. Astronaut. Congr.*, 10 pp. (1960). (*In German.*) It is shown that a photon-gas also exhibits sub-, trans- and supersonic regions. Shockwaves are possible but the existence of an asymptotic behaviour for the ratio of densities in front and behind the shock has not been shown. Sänger's suggested method for the direction of intense photon beams (by the development of electron gas mirrors by means of heavy shocks in a plasma or pure electron gas) has been demonstrated to be impossible. There are only a few possible methods for directing intense photon beams. (11 *refs.*)

8—MISSILES

.1 *General*

[*See also* abstracts nos. 349, 413, 485 and 551]

(650) **On the optimum subdivision of stages in multi-stage missiles.** E. E. H. Schurmann. *Missili*, **1** (3), 33–6 (*June*, 1959). (*In Italian.*) [For original English version see *Jet Propulsion*, **27**, 863–5 (*Aug.*, 1957).]

(651) **Developmental state in 1957 of unmanned aircraft, supersonic rockets and space vehicles.** E. Sänger. *Forschungsinstitut für Physik der Strahlantriebe Mitt.* 12, 143 pp. (*Oct.*, 1957). (*In German.*)

(652) **Missile handling becomes big business.** *Aviation Wk.*, **68** (21), 89, 92, 95, 97, 100, 102, 105, 107 (26 *May*, 1958).

(653) **British missiles 1958.** *Flight*, **74**, 343–6 (29 *Aug.*, 1958). Illustrated review.

(654) **Missiles 1958.** *Flight*, **74**, 861–98 (5 *Dec.*, 1958). Review of the world's guided weapons, and a special feature on Thor.

(655) **1959 Directory of government missile agencies.** $15.00. *Federal Procurement Publications, New York* (1959).

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11—BIOGRAPHY AND HISTORY

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